TECHNICAL UNIVERSITY OF SOFIA

FINAL PROJECT

WIND FARM PROJECT

STUDY AND PLANNING OF A WIND FARM

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DOCUMENT 1:

MEMORY

INDEX

1. ABSTRACT

Wind energy has experimented a boom throughout Europe, especially in countries such as Germany, Italy and Spain. Although it is spreading to other countries as Bulgaria increasingly aware of the importance of renewable energy as an energy resource.

In order to make all this possible, wind energy should be covered within a legal framework that ensures the economic viability of these facilities and to be attractive to investors. In Bulgaria the advances in this technology are increasing as well as the installation of new wind farms. The greatest progress in efficiency of wind turbines is the use of less intense winds, which are more common in this area. This expands the possibilities of wind farm locations allowing an expansion of the sector.

The objective of the Project is located on the Black Sea coast in Bulgaria, specifically in the town of Suvorovo. It consists of an alienation of fifteen wind turbines of 2 MW each, representing a total power of 30 MW.

The first thing that the Project approaches is the sitting of the wind farm from the wind data of the area, which are obtained from a study of winds at two heights; the location of the park is decided by evaluating the potencial areas. However, the criteria for site selection are also presented tending to geographic, agricultural and socio-economic reasons in the area, in addition to the need to assess environmental impacts.

Subsequently several types of wind turbines are evaluated within the market to install at the site chosen, depending on the technical characteristics and the available power of the wind turbine. This selection is decided by a study of productivity with the corresponding wind turbine farm. Finally Gamesa 114 - 2 MW is chosen.

Ones chosen the wind turbine and the location, it is studied the position in which must be installed to not alter the production of those who are next arises.

Finally it is evaluated the transformation of the energy generated by the wind turbines, in this case must transform from 690 V to 20 kV. After evaluating several possibilities opted for the installation of a transformer in each wind turbine, in addition to installing a booking transformer every two wind turbines.

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4. BIBLIOGRAPHY

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5. ANTECEDENT

5.1 GENERAL PRESENTATION

The Project involves the design of a wind farm and connection to the network in an area of medium voltage (20 kV). Project falls within the wind study, the study of the possibilities, the choice of turbine and the installation area.

The student who carried out the project is *Ana Sastre Gómez*, student of the Public University of Navarra in Spain. Its implementation has been developed at the Technical University of Sofia in Bulgaria.

5.2 OBJECTIVE OF THE PROJECT

The objective is through the study of wind make the choice of wind turbines, analyzing both the power and the manufacturer of the wind turbines. Always analyzing everything from the economic point and looking for maximum power and performance.

5.3 TEORY OF WIND AND FUNDRAISING

Coriolis Force

Due to the rotation of the globe, any movement in the northern hemisphere is diverted to the right when viewed from our position on the floor.

Visible effects of Coriolis Force

The named instance of the display occurs when air or water masses move along terrestrial meridians and trajectory and speed are modified by him. Winds or oceans currents that move following a meridian accelerating deviate in the direction of rotation (east) if they go to the poles or the opposite (west) if they go to Ecuador (northern hemisphere).

The effect of the Coriolis Force must always be considered that the movement of fluids study and also of any mobile object on spheres or flat surfaces in rotation.

How it influences the rotation of the Earth on winds: Coriolis Effect

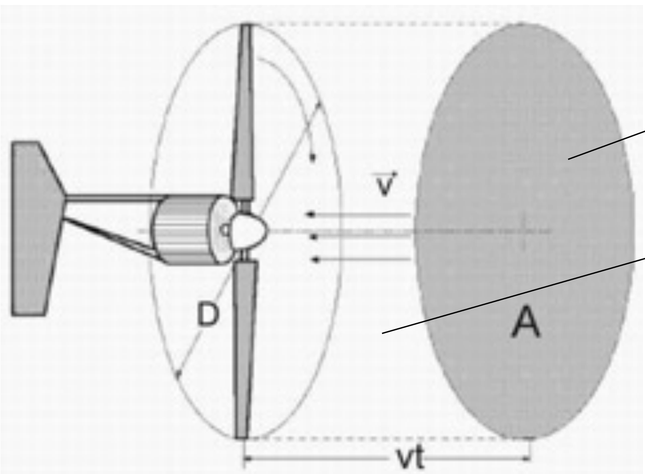
The rotation of the Earth exerts an effect on moving objects on the surface called “Coriolis Effect”. In the northern hemisphere this effect curve its direction of the movement to the right. This is because the Earth rotates from west to east.

Local winds

Although global winds are important in determining the prevailing winds in a given area, local climatic conditions may influence the most common wind directions. Local winds are always superimposed on large-scale wind system, this is, the wind directions is influenced by the sum global and local effects.

Energy of wind: density and a swept area

A wind turbine obtains its power input by converting the force of the wind in a couple acting on the rotor blades. The amount of energy transferred to the rotor by the wind depends on the density, the rotor swept area and wind speed.



Swept Area by the rotor blades, A

Volumen of air that comes in the rotor blades in a period of time, t

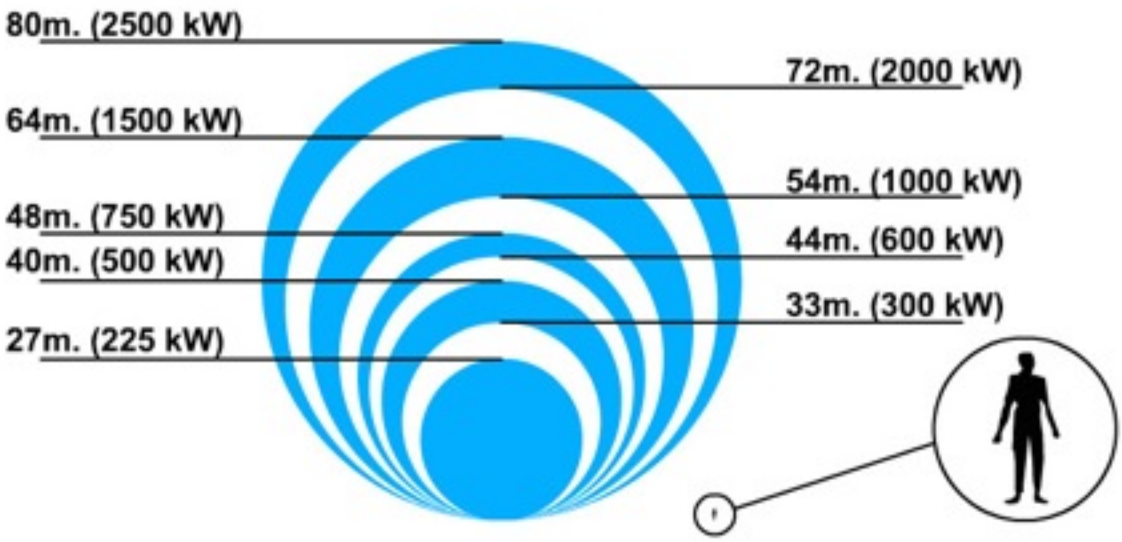
Data: Cylindrical portion passes through the rotor blades. REF:4.

The power produced increases with the rotor swept area

The area covered by the rotor disc (and wind speed) determines how much energy we can harvest in a year.

The drawing gives an idea of the normal rotor sizes af wind turbines: a typical turbine power with a 600 kW usually has a rotor of about 44 meters. If the rotor diameter is double, an area four times higher is obtained. Be obtained from the rotor power available four times higher.

Currently, each manufacturer has its rotor sizes, but most are already over 100 meters in diameter.



Data: Wind power produce by different rotor diameters. REF:4.

Wind turbines divert

A wind turbine will deflect the wind even before the wind reaches the rotor plane. This means it will never be possible to capture all the energy in the wind.

The wind turbine rotor must obviously slow down the wind as it captures its kinetic energy and coverts it into rotational energy. This means that the wind will more more slowly on the output side of the rotor than on the input side.

Since the amount of air passing thought the rotor area must be equal the input and output, air will occupy a larger section behind the rotor plane. It will be explain more extensively in another point of the Project.

6. TYPES OF RENEWABLE ENERGY

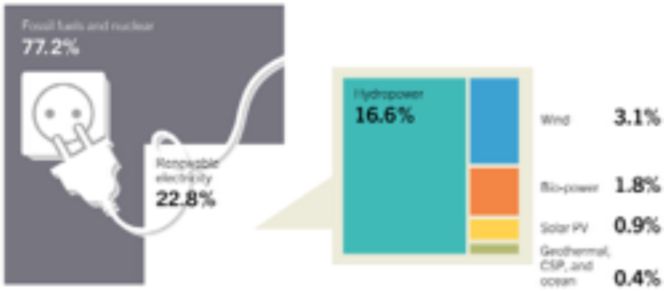
6.1 INTRODUCTION

Historically renewable energies have been the first and the most thoroughly used until Industrial Revolution. Egypt' first boats used to sail with wind power energy, Romans' used hydroelectricity power to their cereals mill, firewood used like biomass to domestic use. Since the Industrial Revolution, they lost significance because of the appearance of energies with elevated production power be made from fossils like coal, oil and, later, nuclear. On the contrary, renewable energies returned to be in peak because of the depletion of the fossils resources and the threats of the environment, this things do that the future is prepared to have an energy supply with a high reduction of dependency of fossils resources. Thus, it is not just a technological and scientist challenge, it is also a political and social challenge that it should based on ethical approaches of society development. At present, it has arrived to the conclusion that energy production is not possible based in ethic judgments, in a fair distribution of the energetic resources called "Social Energy". It is because electric system is a main factor in humanity development in respectable and fair conditions, this parameter is an essential indication of progress and economic of a country; there are huge differences: Island gives a use of 53,203 KWh income per person while Haití gives a use of 50 KWh income per person (datum from *International Energy Agency*).

Renewable energy are those have an inexhaustible power that cover light and heat of the sun, waves, thermal wind, water power and heat power from the plants. Until 2009, they obtained unconditional support of most governments in office by offering incentives for its construction. However, after the economic crisis of 2009, the appearance of public deficits led to the elimination of incentives; which led to a loss situation and overcapacity. According to a study by *Bloomering New Energy Finance (BNEF)* the volume of investment in renewable energies worldwide fell by 11% in 2012. In 2014 renewable energy continued to develop with the growing consumption worldwide and the falling prices of the oil. Also in 2014, renewable energy was extended in terms of installed capacity and energy produced.

Energy experience that took place in 2014 showed the growth of use both variables variables as energy, this increase in the number of countries with renewable energy policies implemented goals.

The data that was completed in 2014 were very positive for the development of renewable energy, as there was unanimous support worldwide increase this type of energy production. The final energy consummation had better datas from others years.



Data: The estimated renewable energy share of global electricity production at end of 2014. REN21.

6.2 HYDROELECTRIC ENERGY

Data: Hydroelectric central of Itapu. REF:4.

Hydropower is the leading renewable source in the world and electricity is generated using the energy provided by the moving water. It produces almost a fifth of the electricity produced worldwide. In addition, it is the cheapest mode of generation today, this is because ones the dam has been built and installed the technical material, the energy resource is free. It has certain drawback; the construction of large infrastructure involved may destroy or affect the flora and fauna of the location, and is a resource that depends on the weather; so it is imposible to control.

A classic hydroelectric plant consist of three parts: a power plant in which electricity is produced, a dam can be opened or closed to control the flow of the water and a reservoirs in which is the water stored. Opening the dam, the water flows through an inlet and presses on the turbine blades, this is chosen according to the height and flow, making these move. The rotation of the turbine rotates a generator coupled to produce electricity. Electricity produced pours transmission lines, depending if is necessary fist pass through a transformer.

Globally have 1,055 GW installed, countries with greater capacity are China, Brazil, the United States and Canada.

Data: Hydropower Global Capacity 2014. REN21.

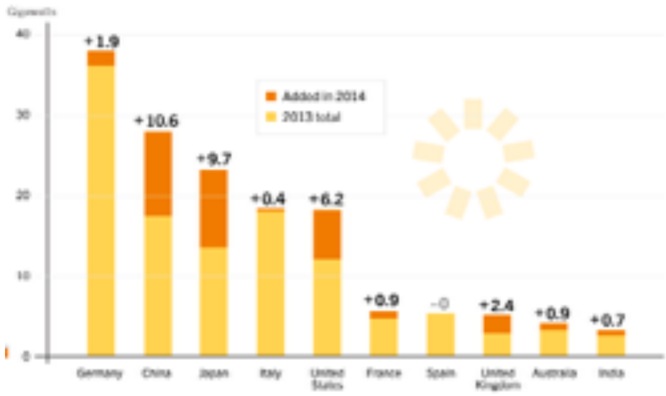
6.3 SOLAR ENERGY

Solar energy is the technology used to harness energy from the Sun and make it usable. Currently it only covers less than one-tenth of the global energy demand. However, the increase has taken place in recent years is very important. Within this type of energy it can distinguish two production modes: one is the photovoltaic cell or solar panels and ,on the other hand, the dollar cell.

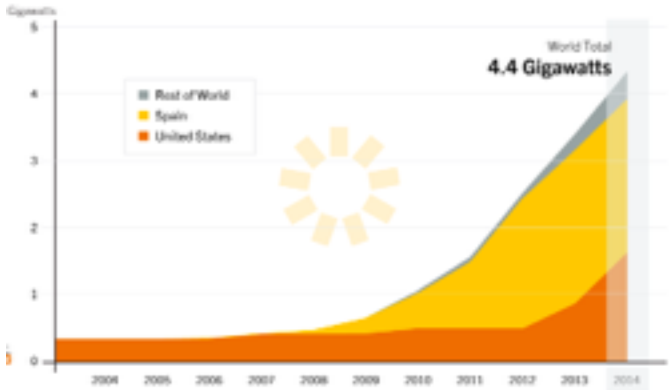
Photovoltaic cells are made of semiconductor materials, usually silicon, which when incident sunlight cause the electrons to separate from the atoms. These are circulated through a set path generating an electric current.

Thermal solar cells are formed by sets of mirrors in a “U” that focus sunlight onto a liquid, oil or rare salts, flowing through the center. This hot liquid boils water, which drives a turbine that is connected to a electric generator.

It is worldwide with 177 GW installed photovoltaic solar energy being the countries with greater capacity Germany, China, Japan and Italy. Solar Thermal energy is less used and is still under investigation, only 4,4 GW have installed mainly in Spain and the United States. The main incentive is the possibility of energy storage as the fluid used could stay hot, even at night can produce energy.



Data: Photovoltaic cells and Solar PV Capacity and Additions in 2014. REN21.



Data: Thermal Solar cells and Concentrating Solar Thermal Power Capacity from 2004 to 2014. REN21

6.4 WIND POWER

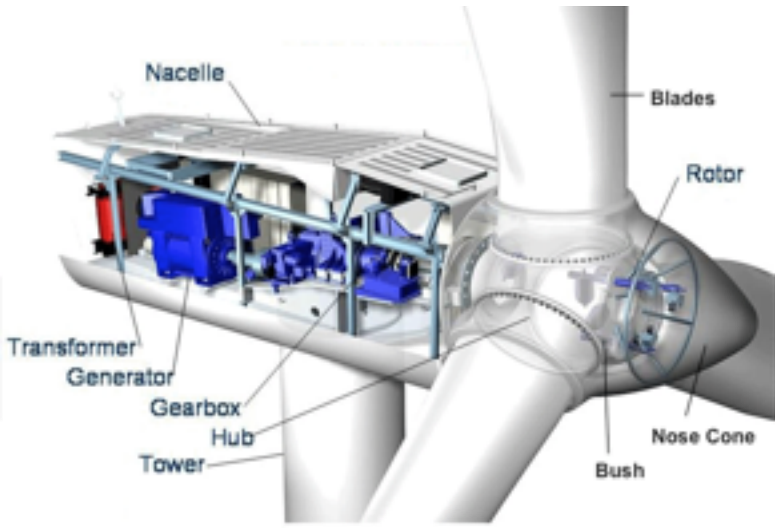
Wind energy is a renewable energy that uses wind power to generate electricity. This is one of the oldest and more explored by human and is today the most mature and efficient renewable energy. The benefits of wind energy are quite clear, does not pollute, it is inexhaustible and is an indigenous energy available in almost the entire planet creating wealth and local employment.

Data: Wind farm.

The device uses for the production of wind energy is the wind turbine, its fundamental principle is the conversion of wind kinetic energy into electrical energy. This conversion is performed by the elements of the wind turbine.

6.4.1 WIND TURBINE PARTS

There are four elementary parts of the wind turbine: rotor, nacelle, tower and foundation, each of which performs a specific function.



Data: Wind Turbine parts and Wind Nacelle elements. REF:4.

- ROTOR

It is the element that captures the kinetic energy of the wind and transfuses to the power train. It is divided into three parts:

- **Nose Cone:** aerodynamic element which is situated in front of the wind direction protruding from the area between the blades and the hub. Its mission is to redirect the wind from the front of the rotor to the nacelle and avoids turbulence in the front of the rotor.

- **Bush:** is the connecting piece between the blades and the main shaft of the mechanical train therefore is responsible for the transmission of kinetic energy into the nacelle. The mechanical connection must be rigidly.

- **Blades:** is the element that directly captures the kinetic energy of wind turning according to wind speed. They must be made of materials with high structural strength and fatigue resistance as they will be under severe inclement weather, strong winds and, in some cases of offshore winds turbines, salinity. They have a complex profile design to help capture more wind energy. They are constructed of a composite polymer matrix reinforcement glass fibers or carbon to toughen.

- NACELLE:

It is the main element of the wind turbine located at the top of the tower, inside are the electrical and mechanical components necessary to covert the kinetic energy that captures the rotor into electrical energy to pour into the network. It is attached to the tower with a degree of freedom to allow the orientation of the wind rotor.

- **Gearbox:** is a device which coverts the low speed and high power of the main shaft at high speed for engine operation. The rotation is transmitted to the generator via the secondary axis. The power train is responsible for transmitting the energy produced by the rotation of the rotor to the generator in a usable form.

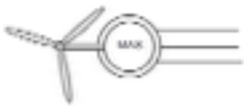
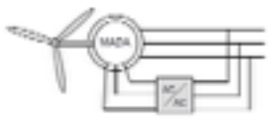
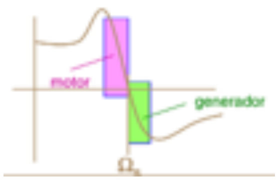
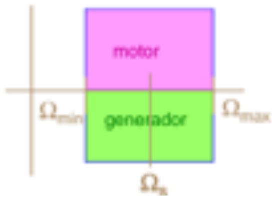
- **Generator:** converts mechanical energy produced by the rotor into electrical energy. Within this element there are different types of generator and connections. The generator and the connection will be chosen by the required features. One of the most important properties for the choose is the option to have variables speed wind turbine or fixed speed.

TYPES OF GENERATORS				
ASYNCHRONOUS		SYNCHRONOUS		
Squirrel Cage Motor	Rotor Winding	Multipole	Permanent Magnets	Independent Excitation
- Easier - Cheaper	- Different speeds of synchronism - It allows extract and inject energy of the rotor	- Optimized control - It does not need gearbox - Low slip	- Easy - It does not Joule losses	- It can regulate the rotor flux
- Less versatility - It does not regulate the power factor - It needs smooth network synchronization	- It requieres synchronization network	- Bigger - More expensive	- It works with the same flow - More expensive	- It has Joule losses

Data: Types of generators.

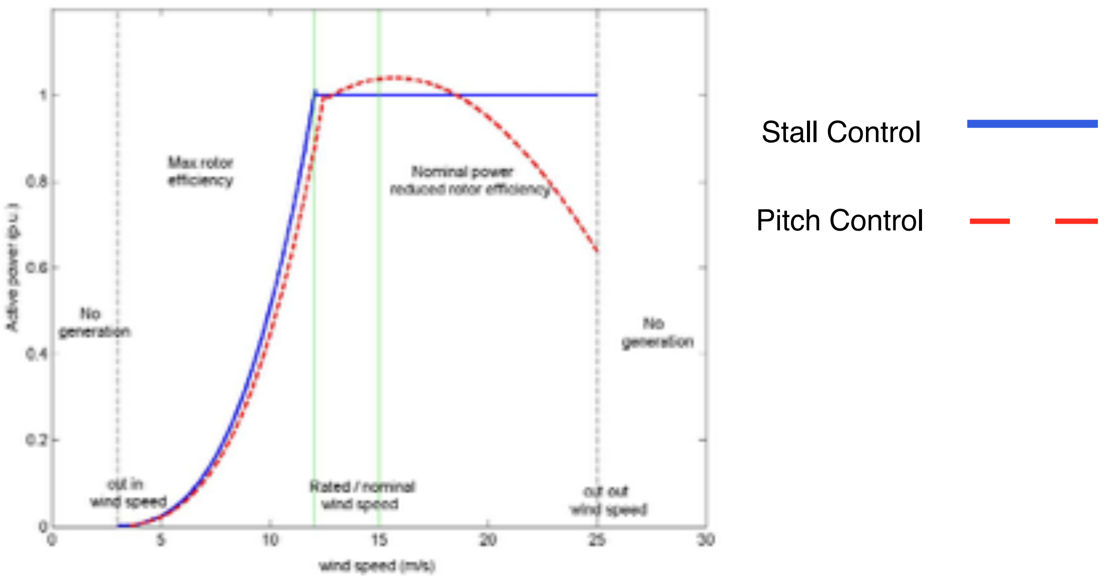
CONNECTION GENERATORS			
ASYNCHRONOUS			SYNCHRONOUS
Direct Network	Full Converter	Doubly Fed (MADA)	Full Converter
- Flatten the squirrel cage machine directly to the network - Very easy - Variable speed - Consumes reactive - Unable to tear	- Variable frequency - Back to back or matrix converter - Powerful converter	- Stator connected directly to the network - Rotor powered by back to back converter - Variable speed - Reduces fatigue	- Variable frequency - Back to back, matrix or diodo bridge converter - Powerful converter

Data: Connection of generators.

COMPARISON OF ASYNCHRONOUS GENERATORS	
Classic induction machine	**Double fed machine**
	
- Cheap and robust - It does not need converter - Worse network integration - Almost fixed speed:	- More complicated and expensive structure - Capture more energy - Reduces fatigue - Variable speed:
	

Data: Comparison of asynchronous generators.

- **Turn system and angulation:** control systems in a wind turbine have two important tasks, the maximum utilization of the wind through guidance and the protection of the rotor turbine at wind speeds that can damage it.



Data: Graph of Wind Power according to wind speed and the wind turbine kind of position. REF:4.

ORIENTATION	It has anemometer measurement and the direction of wind installed in the nacelle equipment. Using an algorithm will move to orient the nacelle.	
POSITION	**Stall control:** the blades do not have a mechanism to vary the orientation angle with the wind. From designed such that for too high wind seeds between losses and slow. While for optimum speeds for maximum power.	
	Pitch control: the blades may vary from angle to changing its aerodynamic hub. It makes better use of the energy gained, especially for high wind speeds, where the rated power is obtained.	

Data: Orientation and position of the wind turbine.

- **Cooling system:** its role is the evacuation of heat generator and other electrical systems that make all the vital parts of the wind turbine, as overheating could cause degradation and possible failure.

- **Breaking system:** wind turbines are equipped with advanced safety systems too. It has several braking systems, which act according to the situation. When the immediate and quick stop of the wind turbine is necessary acts the disc braking system; it will also be used in maintenance situations. On the other hand, if it is looking to slow down or keep it in a value of speed the brakes are used, in case of a system of stall control it uses airbrakes, and in case of pitch control it moves the angle of the blades (it is called "flag position").

- **Transformer:** in most wind turbines it is necessary to adapt the output voltage of the electric generator. This requires a transformer placed at the top or bottom of the tower, this adapts the voltage. It pours into an internal micro grid the wind farm. Subsequently, all the power of the wind farm will become to a substation of medium to high voltage.

- **Protection against electric shock (lightnings):** wind turbines are tall structures that are usually exposed to electric shocks and are therefore very vulnerable to these phenomena. Electric shocks usually affect the tips of the rotor blades. There are different solutions to absorb these lightnings, one of them is to absorb on the blades. The current from the beam passes along the blade through its interior, through conductive metals, subsequently it passes on the nacelle and then go directed down the tower to the ground. The current is diverted from the highly sensitive areas.

- **TOWER:**

It is structure that supports the height of the nacelle and the rotor. By raising components increase the use of wind power that is archived, because the speed will be higher and cleaner. Its design usually consists of a conical or tubular hollow trunk into which there ir the team access to go to the top.

In accordance with that wind turbines can also be found at the bottom the voltage transformer, this transforms the low voltage to medium voltage to be put in the own grid of the park.
The material used for its construction is the steel plates which are then joined in the park. However, in recent years they have started to build composite structures in which the bottom is made of concrete and steel in the top.

- **FOUNDATION:**

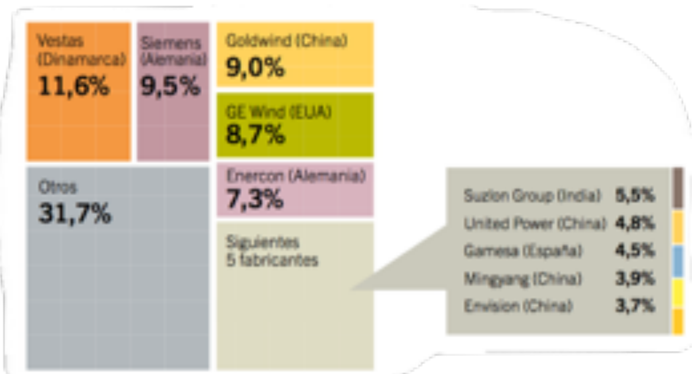
This is a support element like the tower. It consists of an underground reinforced foundation made in concrete, suitable to the terrain and wind loads that have to endure.

6.4.2 GLOBAL WIND ENERGY

There are 370 GW of installed wind power worldwide. Countries with higher capacity are China, the United States, Germany, India and Spain. However, it notes that there are certain countries where wind power intervenes significantly in the electricity market, generating more than 20% of the annual energy, such as Denmark, Nicaragua, Portugal and Spain.

6.4.3 LEADING WIND TURBINE MANUFACTURERS

At present there are lot of manufacturers of wind turbines. However, some companies are clearly leaders in the sector.



Data: Wind Power Global Manufacturers. REN21.

The Chinese wind energy market in 2013 had a strong growth of 16%, it highlights the companies *Goldwind,* that ranked third, and *Envision;* that ousted to several western manufacturers to low position in the ranking. However, it is said that the rise so fast of these companies is due to the home market of which they come. On the other hand, the US market declined due to lower connected wind capacity in the US market. Some of the companies that won more were *Enercon* and *Nordex*, which ensured greater stakes in the wind market, driving a record year for additional capacity in Germany. Despite some financial problems faced by *Vestas*, it remains the first place.

6.4.4 WIND POWER OFFSHORE

Offshore wind follows the same principle as the land being more effective. That is, the wind force is used to move the blades by roaring the electric generator and producing the electric generator and producing electrical energy.

The advantages of installing wind turbines at sea are mainly due to the wind characteristics at sea, it is much more constant and it has less variations and seasons. They also have fewer obstacles to the wind as there are no hills or buildings cluttering its step when changing direction. It is also has more space available to build without invading rural or coastal areas.

In the other hand, the disadvantages offered by offshore wind energy are in their economic majority. Construction at sea right now is much more expensive than terrestrial energy. In addition to the difficulty of construction and repair of wind turbines, making electronics more complicated and can be repair remotely.

6.4.5 FUTURE INNOVATIONS

The most important wind manufacturers constantly conducting studies in order to archive progress in energy production by wind. Presently, short time innovations tend towards building higher wind towers to capture less wind speeds, wind turbines higher power (being built up to 6 MW) and wind turbines with multipole synchronous generators, thus saving the gearbox and can archive an output voltage in medium voltage. Although the most important one is wind power offshore.

There are also studies on wind energy production based directly on the capture mode of the wind. Highlights include two new “wind turbines”:

- **WIND POWER INVELOX:**

It is a project of the American company *SheerWind* which consists in using funnels to catch the wind and could produce 600% more electricity. The wind comes in through a funnel, it narrows and the wind speed increases so the turbine moves faster and produces more. It can accommodate any size unlike other turbines and can generate with lower wind speeds, it needs only 1.6 kilometers per hour.

Data: Wind Turbine Invelox. Rwseene.

- **WIND POWER WITHOUT BLADES:**

The Spanish company *Vortex Bladeless* has chosen generators without blades, which could be installed in urban areas. Instead of using the rotation of the turbine, the raw material is the oscillation that prints the wind on the device. This phenomenon is know as Vortex Shedding because oscillated structures and can cause them to collapse, so it is often critical in designing buildings. These wind turbines reduce the carbon footprint by 40% compared to conventional ones, but also produce 30% less energy than turbines equipped with blades.

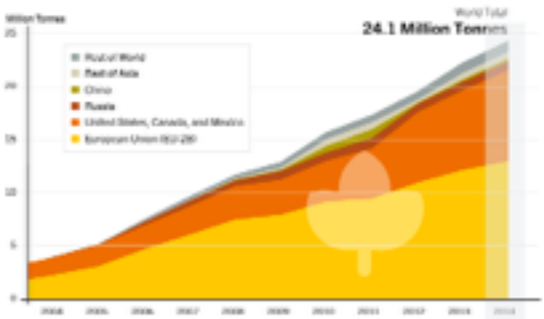
Data: Wind Turbine Vortex Bladeless.

6.5 BIOMASS

Data: Biomass factory. REF:4.

It is the set of organic matter of vegetables or animal origin and materials derived from natural or artificial transformation. Specifically it includes waste from agricultural, livestock and forestry activities and byproducts of food processing industries and wood processing. It is boil in boilers where the material is slowly burning, which also generates ash that can be used later as fertilizer. It is clean energy with zero carbon monoxide emotions because they consume the same amount of CO_2 produced by burning.

It is not very common this generator energy but it is increasing during the years. It is show below some datas about biomass global production.



Data: Wood Pellet Global Production from 2004 to 2014. REN21.

6.6 TIDAL POWER

It is a set of technologies that harness the power of the oceans. The sea has an energy potencial is mainly manifested in the waves, tides, currents and temperature differences between there surface and bottom. It is an energy does not generate significants environmental and vial impacts and is an energy resource with lot of investment.

This is a type of power plant. After storage of waste in the central building are passed to a fuel separation by size. Then they are taken to the boiler for combustion , that causes water pipes into steam due to heat. The steam generated goes towards the turbine which is connected to electric generator and generates electric power.

Data: Tidal Power device. REF:4.

6.7 GEOTHERMAL POWER

It is one of the lesser-known renewable energy and is stored beneath the earth's surface as heat . The heat energy of the earth it is transmuted from its inner layers to the outermost part of the Earth's surface. For the production of electricity high temperature deposits in excess of 100 - 150 are used .

Data: Geothermal factory. REF:4.

7. NORMATIVE

7.1 DISTRIBUTE THE ENERGY

An electric system has as a gol the production of electric energy in the centres of generation, the transport and the distribution of it to the users of the supply system. This point it will focus in the transport and distribution of the energy that it is produced.
The achievement of the correct operation demands huge investments, complicated studies and designs, application of specific national and international rules and a exacting approach.

7.2 BULGARIAN REGULATION

Data: Bulgaria electrical map. NEK.

The Bulgarian electrical system has been recently renovated by the 43rd Government of the Bulgarian Republic. On 7 November 2014 not approved the law by which the former Ministry of Economy and Energy was divided into three: *Ministry of Energy, Ministry of*

Economy and Ministry of Tourism. The current Ministry of Energy is responsible for the regulation of the entire energy market with three main objectives. Their priority is the creation of standards in order to archive a stable and growing economy and carry out energy policy and the economy of legal and desirable manner. Besides seeking the creation of a transparent system where technological advances, increased production and the development of renewable energy are archived. The last point is about foreign systems, it seeks to improve cooperation in the energy system and its integration.

Nowadays, the energy is distributed by the company *Bulgarian Energy Holding* in assisted by the national company *Natsionalna Elektricheska Kompania EAD (NEK)*. NEK acts like a single buyer directly from the power generators on the high voltage grid and remains the sole electricity supplier at regulated prices for the end suppliers. Moreover, NEK has the legal obligation to purchase electricity by Combined Heat and Power (CHP) plants, renewables and industrial producers at regulated prices. Dispatching of power plants takes place based on regulated quota and priority rules. As a result, the company NEK purchases electricity at a wide range of prices, from 21€/KWh to 350€/KWh. However, the Bulgarian electricity market operates mainly at regulated prices, covering roughly half of the electricity transactions. The rules on electricity trade were amended in 2014 by the *State Energy and Water Regulatory Commission: SG 66/26.07.2013*, amend. and suppl. *SG 39/9.05.2014 “Electricity Market Rules” and “Bulgarian Grid Code”.*

It can be divided in four activities:

1. **GENERATION:** the generators factories belong to large private companies, although some of them are public and the government regulates them.

2. **TRANSMISSION:** it is regulated by *Natsionalna Elektricheska Kompania EAD (NEK)*, which is responsible for the construction of new connections and maintenance. It is responsible for transporting energy from the centers of generation to the distribution network.

3. **DISTRIBUTION:** it is no posible to choose which company distributes energy. It depends of the area which company works in:

    - **CEZ**: it is a company from Chez Republic and takes place in the north and the west.

    - **EVN**: it is a company from Austria and takes place in the south and southeast.

    - **ENERGO PRO**: it is a company from Bulgaria and Russia and takes place northeast.

4. **MARKETING:** trading companies are the same companies that distribute the energy. Although there are some private companies that are also working in this activities.

7.3 SPANISH REGULATION

Data: Spain electrical map. REE.

To understand the Spanish electrical system and its operation is divided into four main activities: generation, transmission, distribution and marketing.

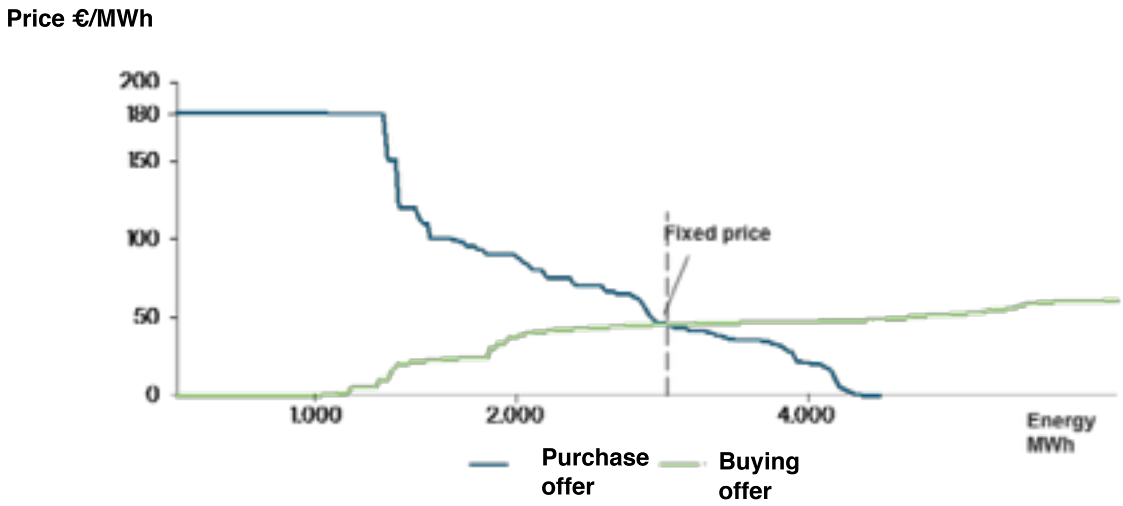
1. **GENERATION:** the generators factories belong to large companies, major companies which represent about 90% are *Iberdrola, Gas Natural Fenosa, Endesa, EDP* and *E.ON.* There are also small generators belonging to private companies.

2. **TRANSMISSION:** it is regulated by "*Red Eléctrica Española" (REE)*, which is responsible for the construction of new connections and maintenance. It is responsible for transporting energy from the centers of generation to the distribution network.

3. **DISTRIBUTION:** it is no posible to choose which company distributes energy. In the north of the country in charge of distribution is *Iberdrola*, while in the south the company that distributes energy is *Endesa*. Although there are other ones that also operated in some areas of the country like *E.ON* and G*as Natural Fenosa.* It is distributed according to the geography.

4. **MARKETING:** trading companies are chosen by the end users.

From 1 January 1998, the electricity market works as follows: there is a daily auction where the producers enterprises and trading companies communicate the price that they want to sell and buy the electricity. The buying-selling of energy is closed with a fixed price for all the companies that enter in the auction. This system is an important incentive to reduce the price of electricity because the generating companies try to offer their energy at the lowest price so they can ensure that their plants are selected to run. Renewables and nuclear energy often sell at zero price, while conventional plants sold at a higher price. This is called **Daily Market.**



Data: Example of auction market. OMEL.

In addition to the daily market, there is an **Intraday Market** and **Ancillary Services Market.** The intraday market is responsible for making some adjustments to the offers and married in the daily market demands. The ancillary services market consists of the processes that solve the imbalances that may arise between generation and demand.

Management agencies are the electricity market operator and the system operator, responsible for economic and technical management:

- **Market operator:** the Company Spanish Electricity Operator *(Operadora del Mercado Español de la Electricidad, OMEL)* is responsible for the financial management of generation. OMEI is the market operator of the Iberian Peninsula (Portugal and Spain).

- **System operator:** Spanish Electric grid *(Red Eléctrica Española, REE)* is responsible for the technical management of the system.

7.4 EUROPE REGULATION AND AGREEMENT

During last years it has occurred some essential changes in the electric sector that have done necessary to set up a new normative period. Stand out between them the high penetration of renewable energy, appearance of new agents and offers more complicated in the energy market. Moreover the capacity excess in order to claim the backup system or like estructural lack. Because of that it has been established a global reform of the sector, it was necessary to provide security, stability and guarantee a sustainable system.

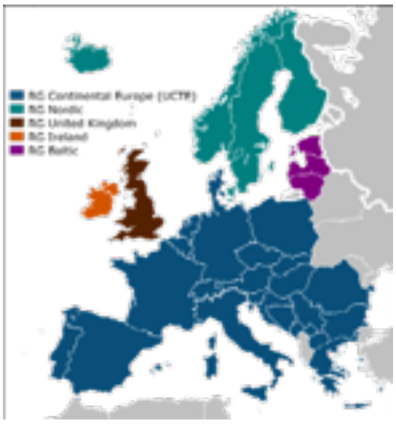
Currently among the challenges facing Europe include the dependence on imports, limited diversification, high and volatile energy prices, growing global demand, security risks for producing countries and for transit, the growing threats of climate change, the challenges posed by the integration of renewable energies, the need for greater transparency and better integration and interconnection of markets across countries. Thus the core of European energy policy consists of a series of mesures to archive an integrated energy market, security of supply and sustainability of the sector. Article 194 of the *Treaty on the Functioning of the European Union (TFUE)* include specific provisions related to the sector.

The main objectives under the *Treaty of Lisbon in energy policy of the EU* are to ensure the functioning of the energy market, ensuring security of supply, promote energy efficiency and energy savings, develop forms of new and renewable energy and promote the interconnection networks. Accordance with *Article 194 TFEU*, some areas become part of a shared policy, which is a step in common energy policy. However, each member maintains its right to exploit different resources.
These deployments were supported by the *European Council*, which in March 2007 adopted an integrated policy in climate and energy and pledged to archive goals since 2007 until 2020: reduction of at least 20% in emissions of gases causing greenhouse effect, an increase of 20% share of renewable energies in energy consumption and 20% improvement in energy efficiency.

7.4.1 INTEGRATION OF THE EUROPEAN ELECTRICITY MARKETS

During the last decade several market couplings have taken place among neighboring European markets, enabling an implicit cross border trade of electricity.

The coupling of the Nordic markets already started at the beginning of the last decade and in June 2013, Latvia became part of the coupled region. In Central Western European (CWE) region a trilateral coupling between France, Belgium and the Netherlands was introduced in 2006, which was extended to Germany in November 2010. In central and Eastern Europe (CEE) a market coupling exists between the Czech Republic and Slovakia since 2009, which was extended to Hungary in September 2012. Poland is also coupled with Sweden and Slovenia with Italy as from the end of 2010. Finally, at the beginning of February 2014 the CWE and the Nordic region was coupled with the UK and Ireland, forming the North



Western Europe (NWE) market, with the participation of fifteen European countries. Since May 2014, also the South-West European Market, Spain and Portugal, are coupled with North-Western Europe.

Data: European electrical zones. REF:4.

These market coupling have also contributed to the convenience in wholesale prices between neighboring markets. However, the existence of markets couplings does not necessarily eliminate price differentials. Market coupling can be a useful tool for promoting the integration of the European wholesale electricity markets within the course of the creation of a single internal electricity market, eliminating welfare losses from cross-border power trade.

7.4.2 CONNECTIONS OF THE EUROPEAN ELECTRICITY LINES

The European electrical connection, in addiction to helping in the creation of a single internal market, helps with the daily energy regulations of each country. If any country has energy deficit or imbalance, international connection lines provide the energy needed to solve it.

Data: European energy exchanges. REF:4.

This pictures shows the amount of Mega Waits (MW) that European countries import and export to neighbors countries.

8. LOCATION: SUVOROVO

8.1 INTRODUCTION

The installation of a wind farm should take into account several factors. First it has to make a study of winds in the area where the turbines are going to be located, wind studies normally performed for 3 or 4 years. For this purpose it has used data provided by *National Institute of Meteorology* and *Bulgaria Eolica* collecting the winds in the area. In addiction to obtaining reliable and closest data that will be given in the tubbiness must be measured at different heights, the weather station which provided the data is located at a heigh of 40 and 70 meters.

The installation of the wind farm will be in the town of Suvorovo, located east of Bulgaria. In the vicinity of this town it is already installed a wind farm of 60 MW. The project is carried out in tis work involves the installation of a new independent park named above.

8.2 LOCATION

It is a town in northeastern Bulgaria, part of Varna Province. The town is located 34 kilometres in the northwest part of the provincial capital of Varna with exactly coordinates: 43º20' N 27º36' E.

Data: Location of Suvorovo municipality. REF:4.

It is located and altitude of 246 meters above the sea and it covers an area of 216 square kilometers with a population of 7,544 inhabitants as of December 2009. Suvorovo Municipality includes the following 9 places:

Town	Cyrillic	Population (December 2009)
Suvorovo	Суворово	4,723
Banovo	Баново	137
Chernevo	Чернево	1,386
Drandar	Дръндар	185
Izgrev	Изгрев	210
Kalimantsi	Калиманци	214
Levski	Левски	173
Nikolaevka	Николаевка	494
Prosechen	Просечен	22

Data: Places included in Suvorovo Municipality. REF:4.

8.3 GEOGRAPHY

Data: The surface adjacent of Suvorovo.GOOGLE MAPS.

The surface adjacent to the location chosen has a large plateau areas, which are analyzed to get the best location for the wind farm. Location study is based on archiving greater efficiency of the turbines of the wind farm.

At the moment, there is installed a Wind Farm that it is explained in the last point so it is not possible to install the Project in that area. It is marked is yellow in the picture.

8.3.1 POSSIBILITIES

It has chosen two different sites to study and analyzed which one will be the best option to the Project.

Data: Possibility 1. GOOGLE MAPS.

Data: Possibility 2. GOOGLE MAPS.

CHARACTERISTICS	POSSIBILITY 1	POSSIBILITY 2
Usable Surface	240 ha	420 ha
Access	Path	Road
Altitude	300	320
Vegetation	Agricultural	Agricultural and part of the forest
Orientation	South	Northwest

Data: Characteristics of the two possibilities.

8.3.2 CHOISE

The wind farm will have small dimensions, the total power to be installed is 30 MW, half the power that the existing farm.

The first possibility is the final area that it will be used to install the wind farm. It has been chosen because has better characteristics than the other one:

- The area is flatter than the possibility 2.
- It avoids the wake effect of the existing wind farm.
- There is agricultural land but not forest.
- According to the study of bird migration does not directly affect, birds cross in the adjacent.
- It will use a path during the construction instead of the municipal road.

Data: Chosen possibility. GOOGLE MAPS.

8.4 ENVIRONMENTAL AND SOCIAL BENEFITS, ADVERSE IMPACTS, MITIGATION MESURES, ECOLOGY AND NATURE CONSERVATION

This section provides a summary of the impacts that causes the installation of the wind farm in the surroundings, the fauna and flora of the location. What is more, the Project is not located close to protected or nature conservations areas. The nearest, Suha Reka, 9 km from the site.

8.4.1 LAND USE PLANNING AND CHANGES

The land on which the wind farm will be developed is currently used for agriculture, mostly for arable and grazing. The overhead power-line also passes though arable and grazing land but, in addition, the route crosses forest owned by the state forestry agency.

All the agricultural land required temporarily during the construction will be reinstalled to agricultural use. The over head power line will similarly affect a small area of agricultural land as permanent agricultural land-take is restricted to the footprint to be constructed. It will also affect the forest, it needs a minimum distance to be maintained between the line and trees. However, the forest council have informed Eolica that the forest area crossed by the project mostly of low commercial value.

8.4.2 WATER RESOURCES

There is only one surface water source in the vicinity of the Project site. No formal hydrogeological research has been carried out in the vicinity of the Project site. However, excavations will not exceed 5 meters in depth because the soil is permeable and the grounder level is low.

8.4.3 FLORA

The impact on the flora of the wind farm site will take place mainly during construction. Impact will be low and not significant like it is said in the section below. The overhead power line route also runs through pasture or arable land for much of its route, and any areas impacted during construction will also be reinstated to agricultural use except for the areas immediately under the pylons.

8.4.4 FAUNA: BIRDS

The information of this point have been obtained for "*The Study on the Migration of Roaming Birds in the Area of the Town of Suvorovo carried out with View to the Investment Initiative for the Construction of a Wind Farm"* of August 26th-October 30th, 2005; and April 1st-May 18th, 2006.

This study aims at collecting basic information about the characteristics of autumn and spring migration of birds in order to assess the risk to birds resulting from the construction of the wind farm northwards from the town Suvorovo. It takes the study of roaming birds and non-roaming birds migration, this ones particularly focuses on species of high protection status.

The total number of birds during the monitored period passed is 118,642. They can be divided depend on the heigh, the season and the specie.

HEIGHT	TIME
From 2 m to 150 m	In the early morning and late afternoon hours
Above 150 m	At noon and early afternoon hours

Data: Table about the time the birds cross in different heights.

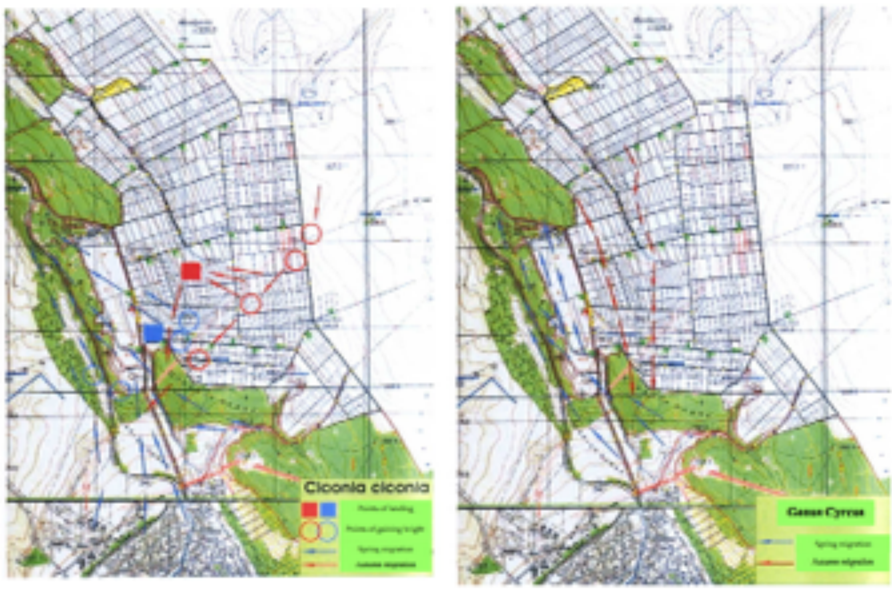
The *conclusions* from the study carried out on Autumn and Spring migration of roaming birds in the area are presented hereby:

- Roaming bird migration was observed in the area of Suvorovo.
- Migration of white stork remained outside the scope of this study.
- The region conforms to be a place of narrow migration front according to the criteria B1 Heapings.
- Totally 4,572 birds of prey passed though the area.
- Three globally threatened birds of prey species were detected.
- About 50% of birds monitored in Autumn and 10% of those monitored in Spring in this area, are flying at a height below 150 m.

Based on the studies and the collected field data and after having analyzed the results and the conclusions made by the Bulgarian Bird Protection Society, the following recommendations are hereby presented:

- The figures represent the migration of some birds and it has to take into consideration.

- The wind turbines should be installed in safe places.



Data: Assessment of risk from collision of migratory birds. REF:3.

8.4.5 LANDSCAPE CHARACTER AND IMPACTS

The Project site is within the South Dobrudzha sub-region of the Danube plain in northern Bulgaria. Within this overall, the wind farm is located at the southern end of the Dobrudzha plateau.

The wind turbines will form dominant vertical features covering part of the plateau. However, no tree removal will be required. Some roads will be built to have access to all the wind turbines.

It is going to study the necessity of construction a new sub-station or used the one which is built during the previous project of wind farm. This point will be studied when the power is calculated.

8.4.6 AIR QUALITY

No public ambient air quality monitoring stations have been set up in the vicinity of the Project site, so no ambient quality data is available. The actual wind farm of Suvorovo does not produces pollution. The Project site is located a considerable distance from significant sources of air pollution, such as main roads, urban areas and industrial sites so ambient air quality is predicted to be good.

Overall, the Project impacts on air are predicted to be low and not significant.

8.4.7 NOISE AND VIBRATION

The key sources of background noise in the area are from town, road, agriculture, domestic noise and Suvorovo wind farm. Background noise is rated as 35-40 dBA at daytime and 30-35 dBA at night.

Noise will be generated during construction and operation. During construction, noise will be generated by plant and machinery and by vehicles. However, impacts are generally transient and confined to small areas of the Project site at any one time. The predicted noise levels lie within admissible levels (55 dBA during the day), and no significant negative impact is predicted. No construction will take place at night. During the time the wind farm is active the noise will be minimum.
With respect to vibration, no impacts are predicted.

8.4.8 SOCIO-ECONOMIC IMPACTS

Unemployment in Suvorovo is higher that the country's average. The wind farm will have a positive impact in terms of providing construction jobs at the beginning and technical jobs during it will be active. It will have increased the economic activity and employment.

Data: Unemployment rate by municipalities in Bulgaria 2015. REF:4.

8.5 STUDY OF WIND

According to the wind study made by the Municipality of Suvorovo, the area is located to the project it is at an altitude elf between 300 and 320 meters. The area covering the place is mostly open, with individual trees and shrubs.

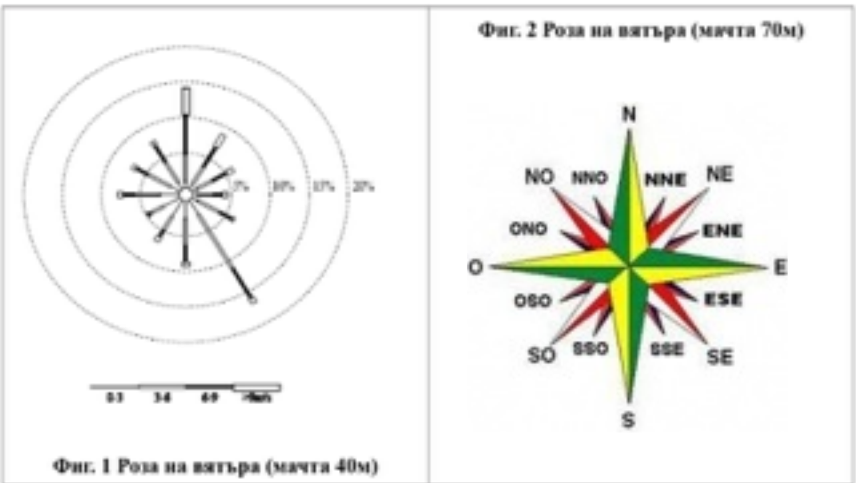
8.5.1 DEVICE OF MESURE

To measure the wind potencial resources posts are installed at different heights of 40 and 70 meters. The instrumentation is located respectively at 20 and 39 meters in the poster of 40 meters, at 20, 40 and 70 meters in the poster of 70 meters.

To study the wind potencial is essential a comparison between measurements on the ground and those from the weather station. Since measurements of the terrain make for relatively short periods of time, the comparison is required in order for this to be done prediction of wind potencial in the long run. In this case, the most appropriate weather station is that of the airport, located about 24 kilometres southeast of the site for the project.

8.5.2 MEASUREMENT RESULTS OF THE WIND RESOURCE

To display information about the distributions of wind speeds and wind frequency variation, it can draw the Rose of the Winds based on meteorological observations of wind speeds and directions.



Фиг. 1 Роза на вятъра (мачта 40м)

Фиг. 2 Роза на вятъра (мачта 70м)

Data: Average of wind speed during the months. REF:3.

The Rose of the Wind is divided into sixteen sectors, each indicating a wind direction. In tis case it can see that the prevailing wind direction is SEE. This information is extremely useful to locate wind turbines. If a large proportion of wind energy comes from a perpendicular direction when a wind turbine is placed in the landscape it will need to have the fewest possible obstacles in that direction. Over the years there may be variations, therefore, it is necessary to have observations from several years to obtain an average. Planners of large wind farms typically have a year of local medium and long-range weather use from nearby weather stations to adjust their measurement to obtain a reliable medium to long term observations.

It is perfectly seen though the chart the predominant wind direction. In this case the prevailing winds are from the south southeast. It is natural then, that the rows of wind turbines are positioned perpendicularly to the direction marked by the prevailing wind.

In the table below are presented the statistical data on the average wind speed all month.

MONTH	AVERAGE WIND SPEED (m/s)
January	7,1
February	6,8
March	7,5
April	6,6
May	6,2
June	5,5
July	6,0
August	5,7
September	6,4
October	6,6
November	6,6
December	7,1

Data: Average of wind speed per month. REF:3.

9. CALCULATIONS

9.1 DIFFERENT KIND OF WIND TURBINES

Once it has chosen the surface used for installation of wind farm and power to be installed, different models and manufacturers of wind turbines will be studied. Having analyzed the possibilities depending on the available power, the power of wind turbines. it will also be important economically the choice.

Five of the top market manufactures turbines will be studied:

MANUFACTURES	TRADEMARK	COUNTRY
Gamesa	Gamesa	Spain
Vestas	Vestas	Denmark
Goldwind	GOLDWIND	China
General Electric	GE	United States
Enercon	ENERCON ENERGIE FÜR DIE WELT	Denmark

Data: Five top wind turbines manufacturers. REF:4.

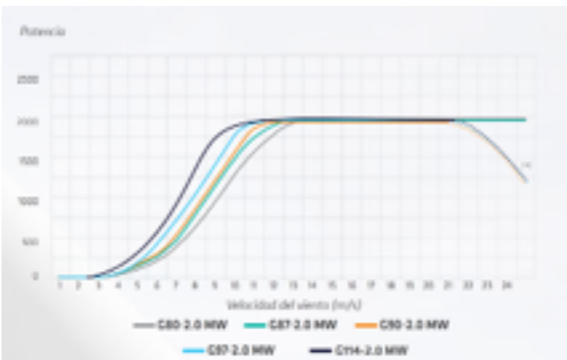
9.1.1 GAMESA

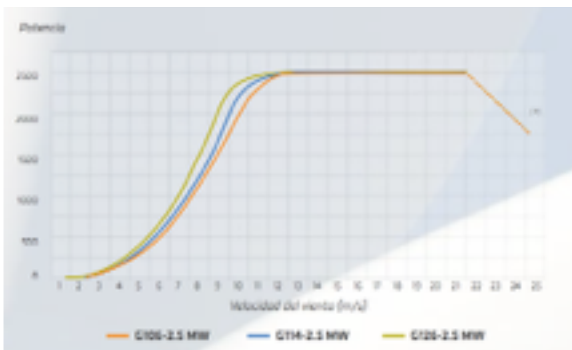
The Spanish company *Gamesa* has different powers of wind turbines, among those existing values will be studied with a power of 2 and 2.5 MW because are the ones that could mold better with the Project.

Data: Example of Gamesa wind turbine. REF.4.

POWER (MW)	NUMBER OF TURBINES	TYPES OF ROTOR (m)	SPEED OF CUT-IN (m/s)	SPEED OF CUT-OFF (m/s)
2	15	80, 87, 90, 97, 114	3	25
2.5	12	114,126	3	25
	TOWER	**CONTROL**	**GEARBOX**	**GENERATOR**
2	Modular	Pitch and variable speed	1 planetary stage 2 stages parallel axes	Doubly fed 690 V AC
2.5	Modular	Pitch and variable speed	2 planetary stages 1 stages parallel axes	Doubly fed 690 V AC

Data: Table of the characteristics of Gamesa wind turbines.





Data: Graphs of speed of wind to power for different rotors and power. GAMESA.

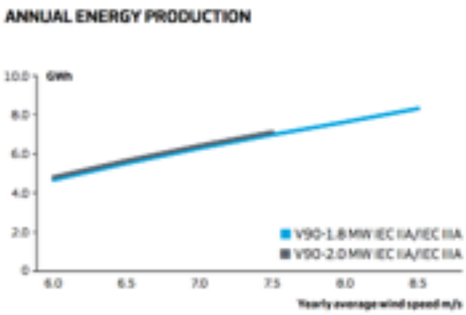
The technical characteristics are very similar in both types of wind turbines. Comparing the two powers and size of rotors of each one, it was chosen as a possible final choice the one of 2 MW wind turbine with a size of 114 meters. This is because the new wind turbines tend to be larger to get more power with lower wind speeds and the region where it is being installed the average wind speed is small

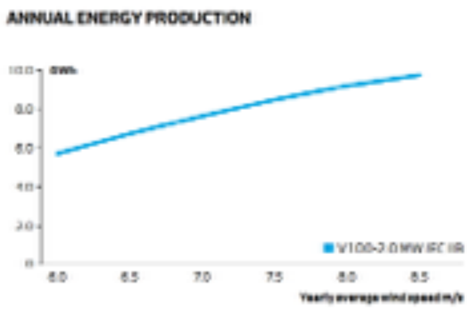
9.1.2 VESTAS

The power value of the wind turbines manufactured by *Vestas* that more conforms to the Project is of 2 MW, which characteristics are in the table below:

Data: Example of Vestas wind turbine.REF:4.

POWER (MW)	NUMBER OF TURBINES	TYPES OF ROTOR (m)	SPEED OF CUT-IN (m/s)	SPEED OF CUT-OFF (m/s)
2	15	90, 100	4	25
	TOWER	**CONTROL**	**GEARBOX**	**GENERATOR**
2	Modular	Pitch and variable speed	2 planetary stages 1 helical stage	Doubly fed 690 V AC





Data: Graphs of speed of wind to power for different rotors and power. VESTAS. Table of the characteristics of Vestas wind turbines.

From this company the turbine wind that ir is going to study is the one with 100 meters of rotor, because the same reasons.

9.1.3 GOLDWIND

The power value that is analyzed in Goldwind manufactures is a power of 1.5 MW.

Data: Example of Goldwind wind turbine. REF:4.

POWER (MW)	NUMBER OF TURBINES	TYPES OF ROTOR (m)	SPEED OF CUT-IN (m/s)	SPEED OF CUT-OFF (m/s)
1.5	20	70, 77, 82, 87	3	25
2.5	12	100, 109, 121	3	25
	TOWER	**CONTROL**	**GEARBOX**	**GENERATOR**
1.5	Tubular Steel	Pitch and variable speed	-	Permanent Magnet Direct Drive Synchronous 690 V AC
2.5	Tubular Steel	Pitch and variable speed	-	Permanent Magnet Direct Drive Synchronous 690 V AC

Data: Graphs of speed of wind to power for different rotors and power. GOLDWIND. Table of the characteristics of Goldwind wind turbines.

After they have been compared, it is chosen the 2.5 MW power because they are necessary less wind turbines than the 1.5 MW.

9.1.4 GENERAL ELECTRIC

In this company like in *Vestas* the power wind turbine that better fit to the project is the one with 2 MW.

Data: Example of General Electric wind turbine.REF:4.

POWER (MW)	NUMBER OF TURBINES	TYPES OF ROTOR (m)	SPEED OF CUT-IN (m/s)	SPEED OF CUT-OFF (m/s)
2	15	107, 116	4	25
	TOWER	**CONTROL**	**GEARBOX**	**GENERATOR**
2	Modular	Pitch and variable speed	Enhanced	Doubly fed 690 V AC

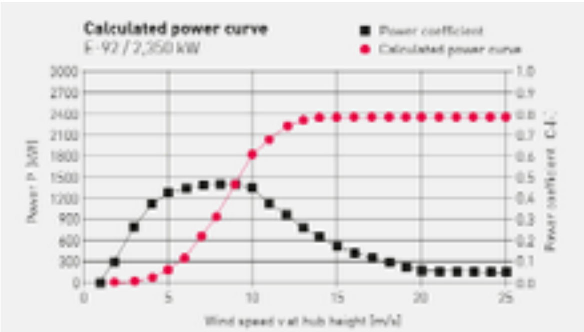
Data:Table of the characteristics of GE wind turbines.

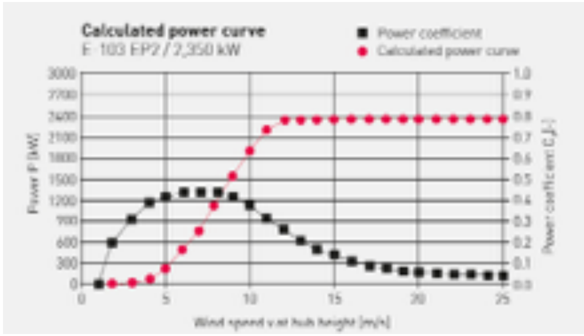
4.1.5 ENERCON

Like the previous companies, the power manufactured is 2 MW.

Data: Example of Enercon wind turbine. REF:4.

POWER (MW)	NUMBER OF TURBINES	TYPES OF ROTOR (m)	SPEED OF CUT-IN (m/s)	SPEED OF CUT-OFF (m/s)
2	15	70, 82, 92, 103	3	25
	TOWER	**CONTROL**	**GEARBOX**	**GENERATOR**
2	Modular	Pitch and variable speed	-	Annular generator





Data: Graphs of speed of wind to power for different rotors and power. ENERCON. Table of the characteristics of Enercon wind turbines

Before the calculations start, it is represented below the wind turbines that have been chosen and their characteristics:

COMPANY	POWER (MW)	ROTOR (m)	AREA (m	HEIGHT (m)
GAMESA	2	114	10,207	125
VESTAS	2	100	7,854	120
GOLDWIND	2.5	109	9,516	109
GENERAL ELECTRIC	2	116	10,568	107
ENERCON	2	103	8,332	103

Data: Companies of wind turbines.

9.2 WIND POWER AVAILABLE IN THE WIND

The first thing that it will be calculated is the power that the wind can proportionate. The wind power depends of different things: density, area and wind speed.

$$P_{available} = 0.5 \cdot \rho \cdot A \cdot v^{3} \qquad (1)$$

ρ = air density (1.225 kg/m^3)

A = swept area (m^2)

v = wind speed (m/s)

WIND SPEED (m/s)	GAMESA POWER (kW)	VESTAS POWER (kW)	GOLDWIND POWER (kW)	GENERAL ELECTRIC POWER (kW)	ENERCON POWER (kW)
1	6.405	4.928	5.971	6.631	5.228
2	51.239	39.427	47.770	53.051	41.827
3	172.932	133.066	161.225	179.048	141.165
4	409.913	315.417	382.163	424.411	334.613
5	800.612	616.048	746.411	828.928	653.541
6	1383.457	1064.531	1289.799	1432.387	1129.319
7	2196.878	1690.436	2048.152	2274.577	1793.317
8	3279.305	2523.333	3057.300	3395.287	2676.905
9	4669.167	3592.793	4353.070	4834.305	3811.453
10	6404.893	4928.385	5971.290	6631.420	5228.330
11	8524.912	6559.680	7947.787	8826.420	6958.907
12	11067.654	8516.249	10318.389	11459.094	9034.554
13	14071.549	10827.662	13118.924	14569.230	11486.641
14	17575.025	13523.488	16385.220	18196.616	14246.538
15	21616.512	15533.299	20153.104	22381.043	17645.614

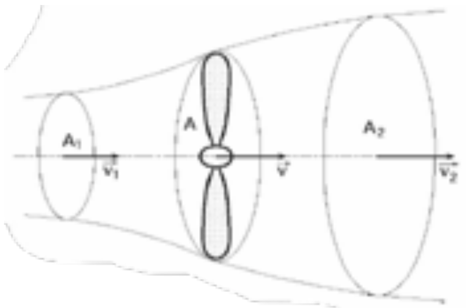
Data: Available wind power.

9.3 MAXIMUM WIND POWER AVAILABLE FOR LIMIT OF BETZ

The *Limit of Betz* says that only can become less than 59% of kinetic energy into mechanical energy using a wind turbine. It was first formulated by German physicist *Albert Betz* in 1919, his book "*Wind-Energie*" provides much of the knowledge that at that time we had about wind energy and wind turbines.

Show Betz Limit is simple to perform as shown below:

It is considered that the wind speed in the entrance of the turbine is "v_1" in cross section "A_1", while the output speed is "v_2" corresponding to the area "A_2". In the area of the rotor section swept by the blades will be "A" and there will be a speed "v". The area A captures some of the energy of moving air that comes down to it, that is the output speed will be less than the input, but never zero ($v_2 < v_1$).



Data: Graphs of speed and area of the Limit of Betz. REF:4.

The mass flow rate is constant, that is, the rule of conservation of mass is true:

$$Q_m = \rho \cdot Q = \rho \cdot A_1 \cdot v_1 = \rho \cdot A_2 \cdot v_2 = \rho \cdot A \cdot v \qquad (2)$$

This equation explains the flow tube widens after the turbine.

It can express the useful power transferred by the wind turbine in two ways:

1) Loss per unit of time kinetic energy of wind passing through the propeller:

$$P_{helpful} = -\Delta E_k / \Delta t = E_{k1} - E_{k2} / \Delta t = 1/2 \cdot \rho \cdot A \cdot v \cdot (v_1^2 - v_2^2) \qquad (3)$$

2) Work generated per unit time by the force of the wind on the area:

$$P_{helpful} = F \cdot v = \rho \cdot A \cdot v^2 \cdot (v_1 - v_2) \qquad (4)$$

Of equations 3 and 4, and recalling that (a2 - b2) = (a+b)(a - b):

$$1/2 \cdot \rho \cdot A \cdot v \cdot (v_1^2 - v_2^2) = \rho \cdot A \cdot v^2 \cdot (v_1 - v_2)$$

$$v = (v_1 + v_2) / 2 \qquad (5)$$

So, in Betz model wind speed in the plane of the propeller is the average wind speeds before and after the same.

$$P_{helpful} = 1/2 \cdot \rho \cdot A \cdot (v_1 + v_2) / 2 \cdot (v_1^2 - v_2^2)$$

if it suppose that $v_2 = bv_1$;

$$P_{helpful} = 1/2 \cdot \rho \cdot A \cdot (v_1 + bv_1) / 2 \cdot (v_1^2 - b^2v_1^2) = 1/4 \cdot \rho \cdot A \cdot v_1^3 \cdot (1 + b) \cdot (1 - b^2) \qquad (6)$$

The maximum value of the power is obtained doing the derivate:

$$P_{max} = dP_{helpful} / db = 0$$

$$(1 - b^2) + (1 + b) \cdot (-2b) = (1 + b) \cdot (1 - 3b) = 0 \qquad (7)$$

This final equation has two possible solutions:

SOLUTIONS **1)** b = -1 (no sens)

2) b = 1/3 so $\mathbf{v_2 = 1/3 \cdot v_1}$

To have the maximum coefficient of maximum power, the right solutions is put in the equation 6:

$$P_{helpful} = 16/27 \cdot 1/2 \cdot \rho \cdot A \cdot v_1^3$$

$$C_p^{\ Betz} = 16/27 = \mathbf{59\%}$$

$$P_{available} = 0.5 \cdot \rho \cdot A \cdot v^3 \cdot C_p^{\ Betz} \qquad (8)$$

ρ = air density (1.225 kg/m³)

$$A = swept\ area\ (m^2)$$

$$v = wind\ speed\ (m/s)$$

$$C_p^{\ Betz} = Limit\ of\ Betz = 0.59$$

WIND SPEED (m/s)	GAMESA POWER (kW)	VESTAS POWER (kW)	GOLDWIND POWER (kW)	GENERAL ELECTRIC POWER (kW)	ENERCON POWER (kW)
1	3.779	2.908	3.523	3.913	3.085
2	30.231	23.262	28.184	31.300	24.678
3	102.030	78.509	95.123	105.639	83.287
4	241.849	186.096	225.476	250.639	197.422
5	472.361	363.468	440.383	489.067	385.589
6	816.240	628.073	760.981	845.108	666.298
7	1296.158	997.357	1208.410	1342.000	1058.057
8	1934.790	1488.767	1803.807	2003.219	1579.374
9	2754.808	2119.748	2568.312	2852.240	2248.757
10	3778.887	2907.747	3523.061	3912.538	3084.715
11	5029.698	3870.211	4689.194	5207.588	4105.755
12	6529.916	5024.587	6087.850	6760.865	5330.387
13	8302.214	6388.320	7740.165	8595.846	6777.118
14	10369.265	7978.858	9667.280	10736.004	8464.457
15	12753.742	9813.647	11890.331	13204.815	10410.912

Data: Available power of Limit of Betz.

9.4 WIND POWER AVAILABLE

In the preceding paragraphs it has been calculated which is the energy contained in an air mass moving and the maximum energy that can be harnessed. However, compliance with the equation of conservation of mass makes all that power is not usable. Besides wind characteristics, the power depends on the operating characteristics of the machine. Although mechanical losses in transmission and electrical efficiency should be on consideration.

The power coefficient of a wind turbine is defined as the fraction of power contained in the wind is actually captured. The coefficient value can never reach 100%, as seen in the previous section the theoretical maximum value is 59%.

$$P_{available} = 0.5 \cdot \rho \cdot A \cdot v^3 \cdot C_f \quad (9)$$

The capacity factor, Cp, is the ratio between the average wind power usable by the machine and the rated power during the period considered.

$$Cf = \int C_p(v) \cdot v^3 \cdot p(v) \cdot dv \,/\, C_p(v_n) \cdot v_n^3 \quad (10)$$

Still in the equation 9 also should be taken into account that the transformation of kinetic energy into electricity is not perfect. Real systems are never ideal, have losses and imperfections, and therefore must be considered a performance factor which is called "η" and always be less than 1. The yield is given by the breakdown of the transmission efficiency of the different blocks, the most inefficient block is the rotor. Normally wind turbines have a yield of 50%, so it is to be used for the calculations below.

$$P = 0.5 \cdot p \cdot A \cdot v^3 \cdot C_f \cdot \eta \qquad (11)$$

ρ = air density (1.225 kg/m³)

A = swept area (m²)

v = wind speed (m/s)

C_p^{Betz} *= Limit of Betz = 0.59*

η = 0.5

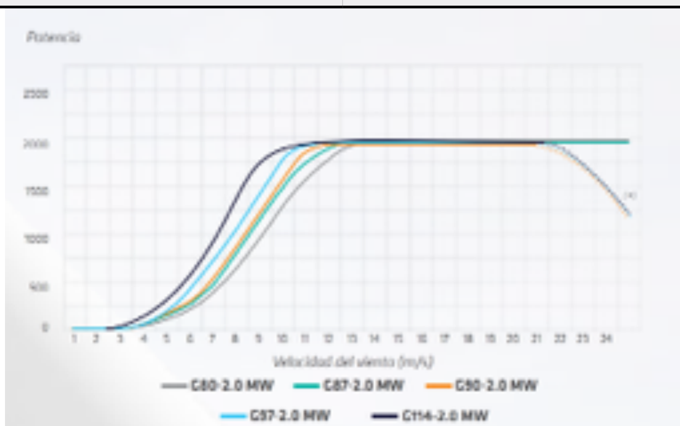
WIND SPEED (m/s)	GAMESA POWER (kW)	VESTAS POWER (kW)	GOLDWIND POWER (kW)	GENERAL ELECTRIC POWER (kW)	ENERCON POWER (kW)
1	1.889	1.454	1.762	1.956	1.542
2	15.116	11.631	14.092	15.650	12.339
3	51.015	39.255	47.561	52.819	41.644
4	120.924	93.048	112.738	125.201	98.711
5	236.180	181.734	220.191	244.534	192.795
6	408.120	314.037	380.491	422.554	333.149
7	648.079	498.679	604.205	671.000	529.029
8	967.395	744.383	901.904	1001.610	789.687
9	1377.404	1059.874	1284.156	1426.120	1124.379
10	1889.443	1453.874	1761.531	1956.269	1542.357
11	2514.849	1935.106	2344.597	2603.794	2052.878
12	3264.958	2512.294	3043.925	3380.433	2665.194
13	4151.107	3194.160	3870.083	4297.923	3388.559
14	5184.632	3989.429	4833.640	5368.002	4332.229
15	6376.871	4906.823	5945.166	6602.408	5205.456

Data: Available power.

9.5 WIND TURBINE CHOSEN

Once the general powers have been calculated for each wind turbine and compared the results, it proceed to choose a particular model and manufacturer in order to obtain concrete values and analyze it in depth.

Broadly it can make a classification of wind turbines based on the average wind speeds that they are able to take advantage. In the study area, the wind potencial is high, but there are regions where the wind potencial is much higher. Therefore the chosen wind turbines will have a rotor diameter large and can capture more kinetic energy. They will also be variable pitch and speed as these features ensure smooth output power and, at the same time, charges are reduced significantly. The height of the wind turbine has been chosen in function of some reasons, the average of wind during the year has not a high value so if the wind turbine is higher may take faster values of wind so the wind increase with the height. It has to take into account that the construction will be more difficult and expensive, although the previous value of height and the chosen one do not defer so much so it is almost the same. Finally, the wind turbine will be installed is of the Spanish company ***Gamesa G114-2.0 MW***. All the characteristics are represented in the table below:

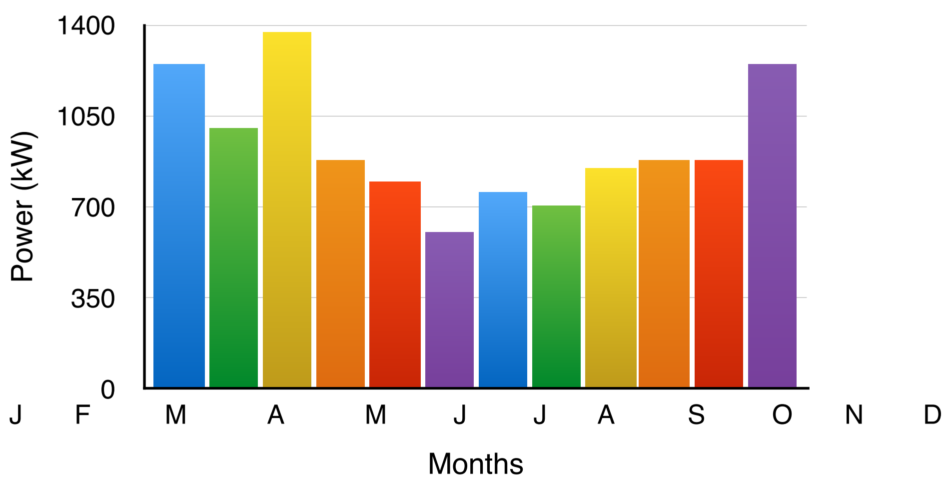
GAMESA G114-2.0 MW		
ROTOR	Diameter	114 m
	Area	10,207 m
	Speed of turn	7.8 - 14.8 rpm
BLADES	Number	3
	Length	56 m
	Perfil	Gamesa
	Material	Fiberglass reinforced with epoxy resin or polyester
TOWER	Type	Modular
	Height	125
GEARBOX	Type	1 planetary stage 2 stages parallel axes
	Ratio	1:128.5 (50Hz)
GENERATOR	Type	Doubly fed
	Nominal Power	2.0 MW
	Voltage	690 V AC
	Frequency	50/60 Hz
	Protection	IP 54
	Power factor	0.95 CAP - 0.95 IND all the powers
GRAPH		

The calculations for the chosen wind turbine and wind speeds obtained by months according to the study of the wind made are represented below:

MONTH	AVERAGE WIND SPEED (m/s)	WIND POWER AVAILABLE (kW)	BETZ LIMIT POWER *Cp = 0.59* (kW)	WIND POWER AVAILABLE *η = 0.5* (kW)	CAPTURE POWER BY THE WIND TURBINE (kW)
January	7,1	2237.584	1320.174	660.087	1250
February	6,8	1965.762	1159.800	579.900	1000
March	7,5	2637.473	1556.109	778.054	1375
April	6,6	1797.364	1060.445	530.222	875
May	6,2	1489.976	879.086	439.543	800
June	5,5	1040.141	613.683	306.842	600
July	6,0	1350.386	796.728	398.364	750
August	5,7	1157.787	683.094	341.547	700
Septembre	6,4	1638.869	966.932	483.466	850
Octobre	6,6	1797.364	1060.445	530.222	875
Novembre	6,6	1797.364	1060.445	530.222	875
Decembre	7,1	2237.584	1320.174	660.087	1250

**Air density value is 1.225 kg/m³. The values of the capture power by the wind turbine have been taken from the graph.*
Data: Power obtained per months with the wind turbine of Gamesa.

According to data obtained normal working range of the wind turbines would be between 600 and 1400 kW (with an average of 934 kW) when the total power is 2000 kW. It is represented below the graph months versus power obtained by the wind turbine:



Data: Graph of the average power all the months.

The month in which the available power is more is in March and the worts months to the wind farm are the summer ones: June, July and August.

9.6 ANNUAL POWER

Here is to calculate the annual energy produced by a wind turbine of kWh/year, this method requieres three steps:

1. Determine the power density (P/A) in watts per square meter of rotor swept area (W/ m^2), on the site and at the height of the wind turbine is expected to install.

2. Calculate the swept area (A) of the rotor of the wind turbine in meters squared (m^2).

3. Take an appropriate value of the total efficiency of the wind system (η). This performance, or overall efficiency includes the efficiency of the rotor, the mechanical transmission and the generator.

Thus, annual energy produced (AEP) in kWh/year is determined by the following formula:

$$AEP = P/A \cdot A \cdot \eta \cdot 8{,}760\ h/year \qquad (12)$$

One way to calculate the power density is using the average wind speed and adequate power factor, or cubic factor (CF). It is expressed as follows:

$$P/A = 1/2 \cdot \rho \cdot CF \cdot v^3 \qquad (13)$$

ρ = air density (1.225 kg/m^3)

CF = Cubic factor = 1.91

v = wind speed (m/s)

MONTH	AVERAGE WIND SPEED (m/s)	P/A (W/m
January	7,1	418.711
February	6,8	367.846
March	7,5	493.541

MONTH	AVERAGE WIND SPEED (m/s)	P/A (W/m
April	6,6	336.334
May	6,2	278.814
June	5,5	194.638
July	6,0	252.693
August	5,7	216.653
Septembre	6,4	306.676
Octobre	6,6	336.334
Novembre	6,6	336.334
Decembre	7,1	418.711

Data: Power per are of the wind turbine each month.

In order to calculate the AEP, it is going to calculate at the first time the production each month and later add all the months:

$$P/A = 1/2 \cdot \rho \cdot CF \cdot v^3 \cdot HM \qquad (14)$$

ρ = air density (1.225 kg/m³)

CF = Cubic factor = 1.91

v = wind speed (m/s)

HM = hours in the month (h)

MONTH	HOURS IN THE MONTH (h)	AVERAGE WIND SPEED (m/s)	P/A DENSITY POWER (W/m	Ph/A ANUAL DENSITY (kWh/m
January	744	7.1	418.711	311.521
February	672	6.8	367.846	247.193
March	744	7.5	493.541	367.195
April	720	6.6	336.334	242.161
May	744	6.2	278.814	207.438
June	720	5,5	194.638	140.139
July	744	6.0	252.693	188.004

MONTH	HOURS IN THE MONTH (h)	AVERAGE WIND SPEED (m/s)	P/A DENSITY POWER (W/m	Ph/A ANUAL DENSITY (kWh/m
August	744	5.7	216.653	161.190
Septembre	720	6.4	306.676	220.807
Octobre	744	6.6	336.334	250.233
Novembre	720	6.6	336.334	242.161
Decembre	744	7.1	418.711	311.521
Total	8760			2889.560

Data: Density power and annual power per month for one wind turbine.

This method is not an exactly one but it is useful to calculate an average power in a year. Do not forget that has been used a frequency distribution of velocities of Rayleigh. A more approximate value to be expected when the frequency distribution of the wind speeds at the site, with which the power density is determined more accurately known.

TOTAL POWER ONE WIND TURBINE	
Anual Density (kWh/m	2889.560
	x
Area (m	10,207
Total Theorical Anual Density (kWh/year)	29,493,738.92
	x
Performance η	35%
Total Real Anual Density (kWh/year)	10,322,808.62

Data: Total annual power for one wind turbine.

The anual production of the whole wind farm will be the production of all the wind turbines, so the power obtained for one must be plus 15, the number of wind turbines that will be installed.

Annual Power Wind Farm = 10,322,808.62 · 15 = 154,842,129.3 Kw·h = **154,842.1 MW·h**

This is the theoretical energy of the farm. Now to get the real power it should apply a correction factors: losers of availability, losers of transport and losers of maintenance.

- **Losers of availability:** 0.98; contemplate the possible breakdowns experienced by wind turbines and prevent their operation for the duration.

- **Losers of transport:** 0.97; they occur in the evacuation line and inside the wind farm.

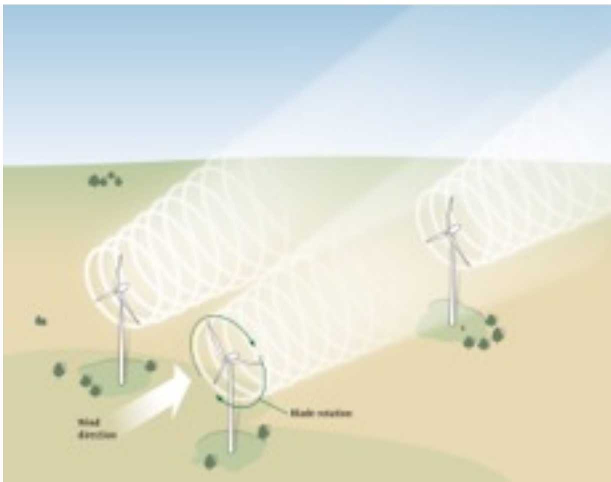
- **Losers of maintenance:** 0.97; the set is not working due to a maintenance shutdown.

Final Annual Power Wind Farm = 154,842.1 · 0.98 · 0.97 · 0.97 = **142,777.1 MW·h**

10. CONSTRUCTION

10.1 DISTANCE

To achieve greater efficiency in the wind farm is important to properly calculate the distance between wind turbines. Wind turbines can cause interference with each other due to the slipstream effect, this effect produces disturbances in the wind after entering the turbines.



The wing distance should be calculated not follow a particular law but is governed by experience. According to *Endesa Red Chair* where Óscar Alexis Monzón Alejandro, in his project *"Design of a wind generation 20MW*" indicates that the distance between wind turbines in the same row will never be less than two rotor diameters and among the wind turbines in a row and the other, there will always be a distance than eight diameters. These distances is to avoid the shadow effect, the effect wake and aerodynamic interference.

Data: Imagine of the wake effect in wind turbines. REF:4.

Charles Memeveau, who studies fluid dynamics at *Johns Hopkins University* developed a model to calculate the optimal spacing between turbines to get the maximum performance. Wind turbines should be located at an adequate distance between them for the named purposes and, with them, increasing turbulence and loss of power. The optimum spacing is located between 8 and 12 times the diameter of the rotor in the wind direction, and between 2 and 4 times in the direction perpendicular to the wind.

10.2 MAP

According with the previous point, wind turbines have different options to be built. These options are going to study below.

To begin, the mesures of the space chosen are 2 kilometers long and 1.2 kilometers wide. The rotor diameter is 114 meters so the distance could be:

- **Wind direction**: it is taken 8 times of the rotor diameter so the distance should be 912 meters. The distance between the wind turbines must be at least 1 kilometer.

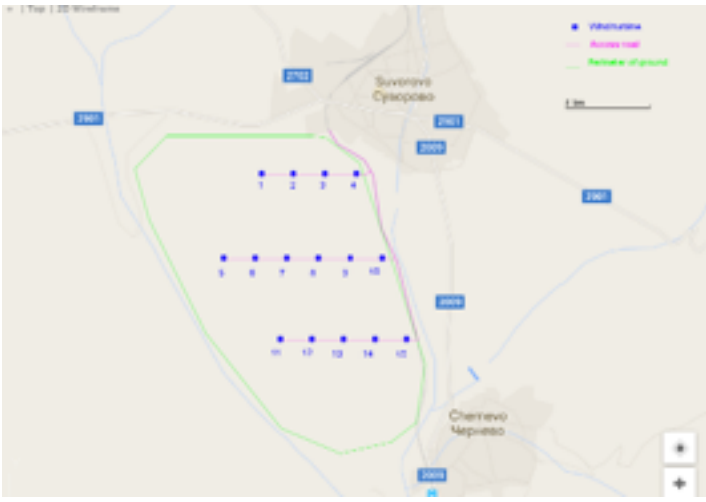
- **Perpendicular wind direction**: it is taken 3 times of the rotor diameter so the distance should be 342 meters. The distance between the wind turbines must be at least 350 meters.

After the distances are calculated, it is exposed two different options in order to analyzed and which one is better, one thing to take into account is that original space has to be increased because the distance between wind turbines must be long.

	OPTION 1	**OPTION 2**
Total wind turbines	15	15
Number of lines	3	4
Number of wind turbines in each line	- Line 1: 4 - Line 2: 6 - Line 3: 5	- Line 1: 2 - Line 2: 5 - Line 3: 5 - Line 4: 3
Distance between lines	1 kilometer	1 kilometer
Distance between wind turbines in the same line	350 meters	350 meters

Data: Options of location.

Then the final maps of both options are represented, in each cases are in a real scale in order to have a real view of the wind farm and more guidance.



Data: Map of the first option. AUTOCAD.

Data: Map of the second option. AUTOCAD.

Once both option have been represented, one of them must be chosen. In this case, the first option has been chosen because some reasons which are almost economical: the path to built will be less than in the other, the agricultural ground used is less, wind turbines are closer so it is better in order to built the sub-station and in case they need to be repair and control.

10.3 FOUNDATION AND PATH

10.3.1 FOUNDATION

Before installing the wind turbine must prepare the ground. In case of wind turbines on land, they are supported on the ground by superficial foundation, and/or some sort of deep treatment or special foundation, according to the ground conditions.

The task to play by the foundations to ensure the stability of the tower during its lifetime, something that gets transferring the loads of the ground. Virtually all of the vertical load comes from the weight of the tower, the nacelle and the blades, but the most significant burden to bear is the one that comes from the stresses caused by the wind. Because of its high altitude, the horizontal force causes a considerable bending moment in the foundation, usually foundations are often characterized as being shallow and very surface in contact with the ground even if the soil characteristics are very unfavorable, usually incorporate piles.

The security required by wind turbines depends largely on the stability and proper functioning of the foundation, both during the construction phase and during the operation phase. The study of geothermal foundation requieres characterization, design requirements and the calculation procedure.

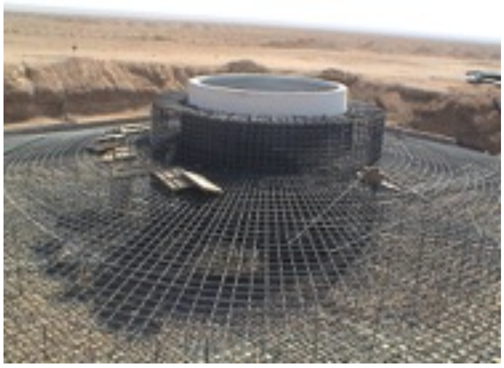
There are also ground improvement techniques for safety. The application of soil improvement techniques has demonstrated its high viability, ensuring the smooth operation of the turbines and reducing costs and deadlines. By type of technique used and the solution adopted it has been able to ensure the bearing capacity, safety against rollover mitigation tender permissible level seats and rotation of the foundation.

Among the types of foundation that have been carried out for wind turbines on land are different types: ground foundations and foundations with piles. Depending on soil conditions, it will choose one or the other type of foundation, shown in the following table:

TYPE OF GROUND	TYPE OF FOUNDATION
Rock next to the surface	Reinforced concrete surface leaning against the rock and anchored by bolts
Firm ground	Superficial reinforced concrete (can incorporate piles)
Low ground bearing capacity	Superficial reinforced concrete pilos

Data: Examples of foundations of wind turbines.

The foundation is made of concrete and there are six steps:



1. It must make a hole in the ground about 20x20x2 meters.

2. A 10 centimeters layer must pour called "cleaning concrete". It used to have a perfect alignment of the field.

3. It has a lower grille and a number of marble plates are placed so that the iron reinforcing mesh is perfectly support. And its put it.

4. It is put the ferrule, in order to level the interior platform is supported in three legs and another three support points for a correct leveling.

5. Ones the concrete has been pouring, superior platform is put in.

6. Grounding wires are placed earth and the platform is draining.

Data: Examples of foundation.REF:4.

The grounding cable is conduced in a mill to another. This cable prevents leakage currents may hurt someone or break something. The drain installation is just to leave an open tube into the foundation and the other end grounded.

The total volume of the foundation will be:

$$20 \cdot 20 \cdot 2 = 800\ m^3$$

$$800 \cdot 15 = \mathbf{12{,}000\ m^3}$$

10.3.2 PATH

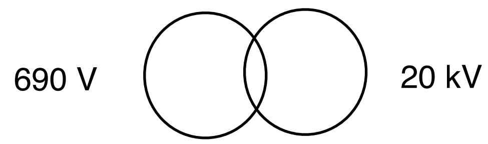
It is necessary to built access roads in order to come in during the operation phase and the construction phase.

In this project we have a way of existing land, however it must build access roads to the three lines of wind turbines to be built. In total it is needed around 4 kilometers.

11. VOLTAGE TRANSFORMATION

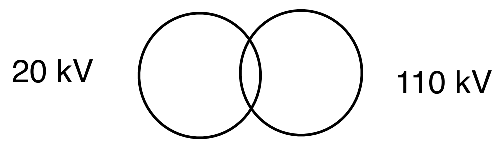
11.1 VOLTAGE REQUIRED

The output voltage of the wind turbine is 690 V, the line its wants to accede is medium voltage, 20 kV. Therefore, transformers low to medium voltage needed.



Data: First transformer.

After the first processing a second transformation of medium to high voltage would be required. However, this is not within the Project.



Data: Second transformer.

11.2 TRANSFORMATION

The transformation of the power is performed via a transformer. The transformers will be installed at the base of the wind turbine, it is necessary to study the number and power of each one.

11.2.1 POSSIBILITIES

The possibilities are based in the number and the power of the transformers.

1. *POSSIBILITY 1*

Place two transformers in each wind turbine with a power of between 1200 - 1400 kVA. In normal operation both transformers would be used, since the total power of each wind turbine is 2 MW. With this possibility if one breaks, the other would be used to transform all the power it could be possible.

With this option the total number of transformers required is 50, all of them with the same power.

2. *POSSIBILITY 2*

Place one transformer in each wind turbine with a power equal than the nominal power of the wind turbine, 2000 kVA. Besides, it would place one transformer more for two wind turbines called booking transformer. In normal operation it will be off, however when one of the transformer breaks, the booking operation will be on.

With this option the total number of transformers required is 22, all of them with the same power.

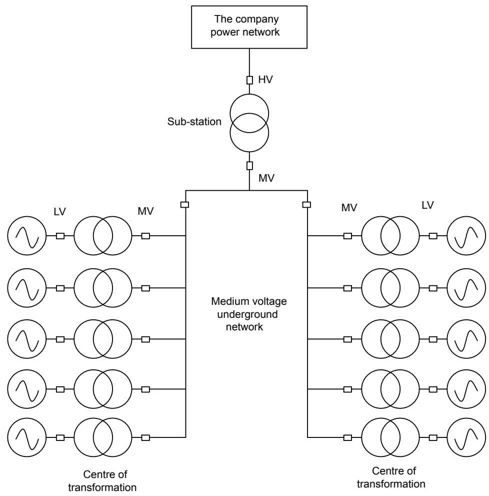
11.2.2 CHOICE

Finally, it is chosen the second possibility because the number of transformers are less than in the other possibility so it would be cheaper. Although the power would be high, the price is not so different. Besides, the out-power could be always the highest because the power of the transformers is the same as the wind turbine.

The electric system of the wind farm is form by the next elements:

- Wind turbines
- Centre of transformation
- Medium voltage underground network

- Sub-station
- High voltage discharge



Data: Schematic representation of the electrical system in the wind farm. AUTOCAD.

11.2.3 TRANSFORMER

The centre of transformation can be placed inside or outside the tower, but very close to it, since it is generated in low voltage the distance does not be long in order to archived to reduce losses. In this case it will be located inside.

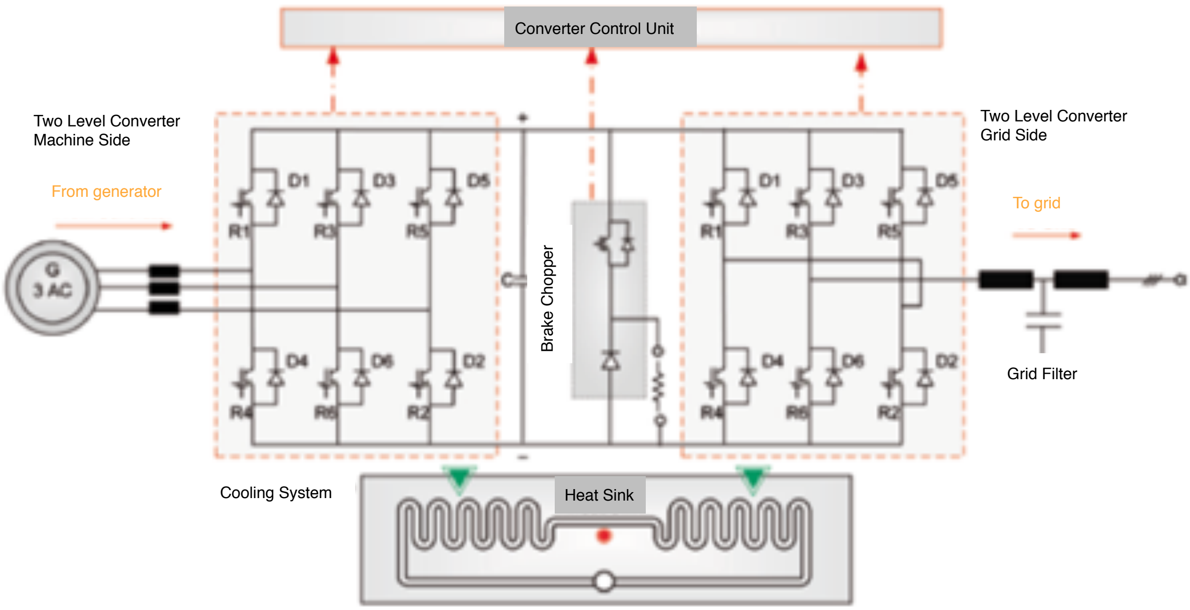
The transformer arrangement within the tower leads to that it should be dry type. the transformation ratio is 0.69/20 kV and the connection is triangle - star (Dyn11).

The transformer power is given by the rated power of the generator and the power factor, in this case is 2,000 kVA. To adjust at the working conditions of the wind turbine, with a number of hours at nominal power reduced, it is designed with lower iron losses and higher in copper.

The protection of dry type transformers is based on the temperature control of their windings with PTC sounding lines. Protection LV side of the centre of transformation depends on the location of it. In those located inside the tower, protection is not necessary as the length of the cable is minimal. For MV side it is often used a switch-circuit breaker that protects the transformer against overloads, associated with a fuse that does the protection against short-circuit.

This protection should be robust enough to allow the transformer inrush current and sensitive enough to detect faults in the transformer LV terminals with a current limited by the impedance missing.

The converter is going to install is from a Spanish company called *Ingeteam:* ***Full Converter - LV,*** the characteristics are summarized here although in the annex it will be all the characteristics pages.



Data: Connections of the converter. INGETEAM.

Data: Converter of Ingeteam. INGETEAM.

11.2.4 MEDIUM VOLTAGE NETWORK

The connection of wind turbines to each other is performed through a medium voltage network. Installation is underground to avoid environmental impact involved an airline. Besides, it has the advantage of greater ease and safety for maintenance and repair operations.

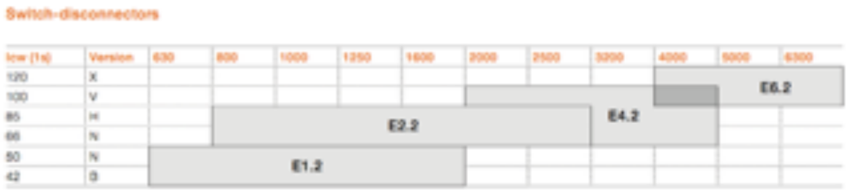
Medium voltage must be used to reduce losses by voltage drop. The cables used are single-pole insulated plastic: polystyrene cross linked or ethylene propylene. Besides, all electrical equipment and grounding cables will go into a trench under a layer of selected sands, there are a total of approximately 3.5 kilometers. Every meter of road must be accompanied also by a ditch where flow into all water in case of rain. Ditches will be on the side where the trench is not and at the angle of 45 degrees and preferably on the side of more inclination. The water will be channeled to reach a place where not pose a major problem, the drains water should be done by concrete.

11.2.5 SWITCHES

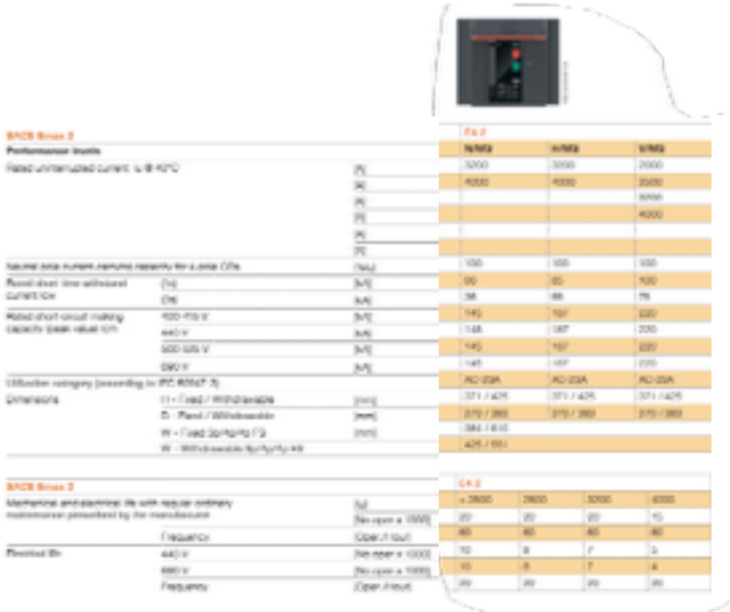
As it will be seen in the electric plane, two types of of switches are used in the project:

- **Switches:** it is a device able to interrupt or open an electrical circuit when the intensity of the electric current flowing exceeds a certain value or that a short-circuit in order to prevent damage to electrical equipment. They can be rearmed ones located and repaired the problem that caused the short or automatic deactivation.

The switch chosen is from the company *ABB.*
SACE Emax 2 - IEC E4.2.: it is the new circuit breaker 4000 A, designed to provide high cutting powers and resist currents up to 100 kA for 1 seconds without special precautions.



Data: Current of switch disconnectors. ABB.



Data: ABB switch.

- **Circuit-breaker:** it consists in isolate an electrical system or electric circuit in the network, leaving this installation without load or empty. This is a mechanical device capable of maintaining an electrical installation slow break, since it depends on manipulation of an operator. It must necessarily follow a ser order for disconnection of the circuit:

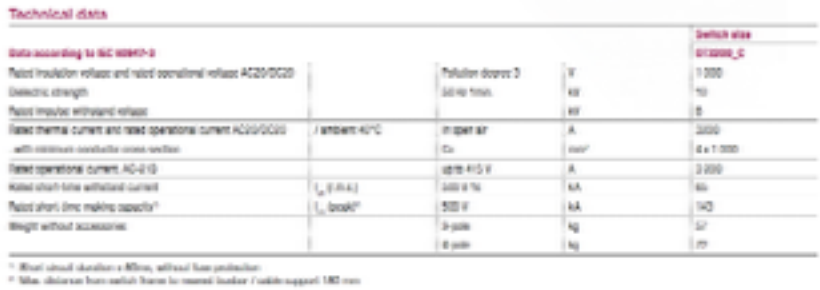
    1. Off the main switch.
    2. Disconnection of circuit-breaker.
    3. Placing the safety lock of circuit-breaker.

  For the connection process proceeds inversely:

    1. Connecting the circuit-breaker.
    2. Connecting the main switch.

  It can be accompanied by fuses according to their physical characteristics.

The circuit-breaker chosen is also from the company *ABB*.
IEC 60947-3 OT3200_C: is a change-over switch advanced and compact especially when compared to different transfer device technologies.



Technical data

Data according to IEC 60947-3				Switch size
Rated insulation voltage and rated operational voltage AC20/DC20		Pollution degree 3	V	1 000
Dielectric strength		50 Hz 1min.	kV	10
Rated impulse withstand voltage			kV	8
Rated thermal current and rated operational current AC20/DC20	/ ambient 40°C	in open air	A	3200
with minimum conductor cross-section		Cu	mm²	4 x 1 000
Rated operational current, AC-21A		up to 415 V	A	3 200
Rated short-time withstand current	I_{cw} [illegible]	[illegible]	kA	[illegible]
Rated short-time making capacity	I_{cm} (peak)	500 V	kA	143
Weight without accessories		3-pole	kg	57
		4-pole	kg	77

[illegible]

Data: ABB switch-breaker.

11.2.6 BOOKING TRANSFORMER

Booking transformers will be installed one for two wind turbines. These ones are necessary in order to be on when one transformer is broken out. They will be installed outside the wind turbine.

The wind farm has 15 wind turbines so one booking transformer will be connected with three normal using transformers.

11.3 COMMUNICATION LINES AND GROUNDING

The communication network of the wind farm is based on connecting all wind turbines to the control station via a fiber optic cable. In the building control all operations are controlled.

All wind turbines will be communicated through a network of ground executed with a cable 70 mm section and equipotential in order to protect the installation in case of electrical failure or lightning,

Wind turbines also have a device in the rotor blades against lighting. It is metallic circles on the tips of the turbine blades, which absorb and transmit the lightning to the ground throughout a ground wire.

11.4 CONTROL BUILDING

The control center is the building from which the wind turbines are controlled. To the building all the cables come from the wind turbines. It is usually located next to the electrical sub-station, where it is transformed from 20 kV to 110 kV.

12. CONCLUSIONS

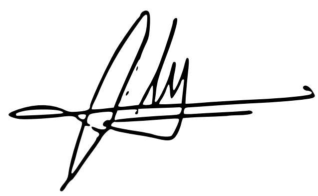
Wind farm installation brings great benefits to the area on the socio-economy, creating lots of jobs, both direct and indirect, that would contribute to regional development. It would also allow the sustainable of the area, due to the generation of clean energy without carbone dioxide emissions, improving air quality and avoid the consumption of the conventional energies, which are more polluting. Globally, it would help to reduce the greenhouse effect.

On the other hand, it must take into account that requieres a large investment. There is talk of both investments, a previous investment cost of the wind study because it takes about four years. As a further investment, once the decision of its construction, due to the overall cost of the installation, purchase of equipment, human resources, etc. The factor that is more negatively affected by the installation of the wind farm is the landscape of the area.

The goal value of the impact on the immediate environment of wind turbines and the Park as a whole is consistent within the entire Project. As for the wildlife, the impact on the environment is moderate after the study. The biggest impact that the Project will provoque of the local agriculture as will stop during the time period that is under construction.

Global production of the wind farm will be sufficient for the consumption of the area during the year. Therefore the project is realizable useful for the area.

Fdo. Ana Sastre Gómez

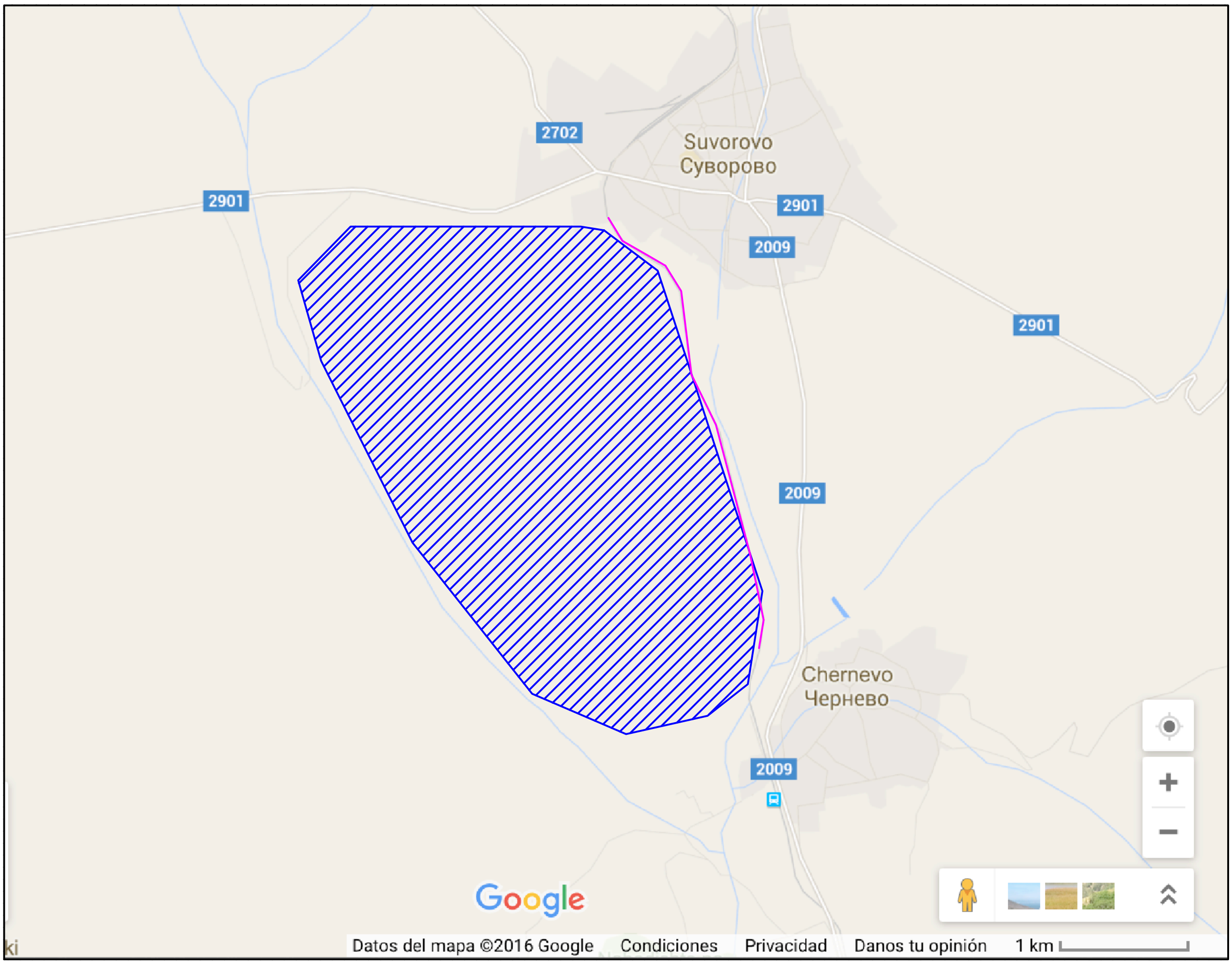


Sofia, 27 mayo 2016

DOCUMENT 2:

PLANS

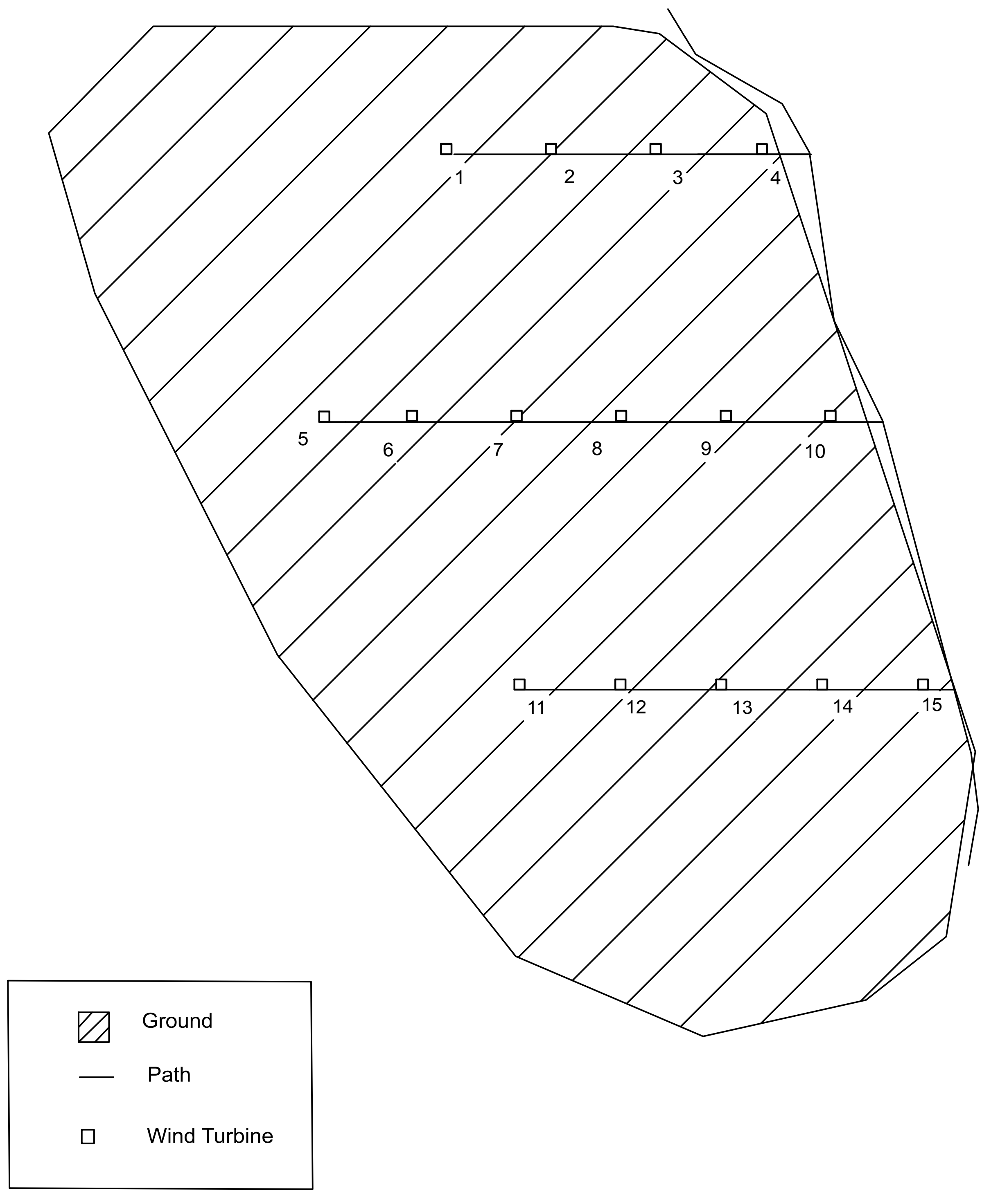
1. GOOGLE MAPS LOCATION
2. LOCATION OF WIND TURBINES
3. GROUNDING OF WIND FARM
4. ELECTRICAL CONNECTIONS OF TWO WIND TURBINES
5. ELECTRICAL CONNECTIONS OF THE WIND FARM



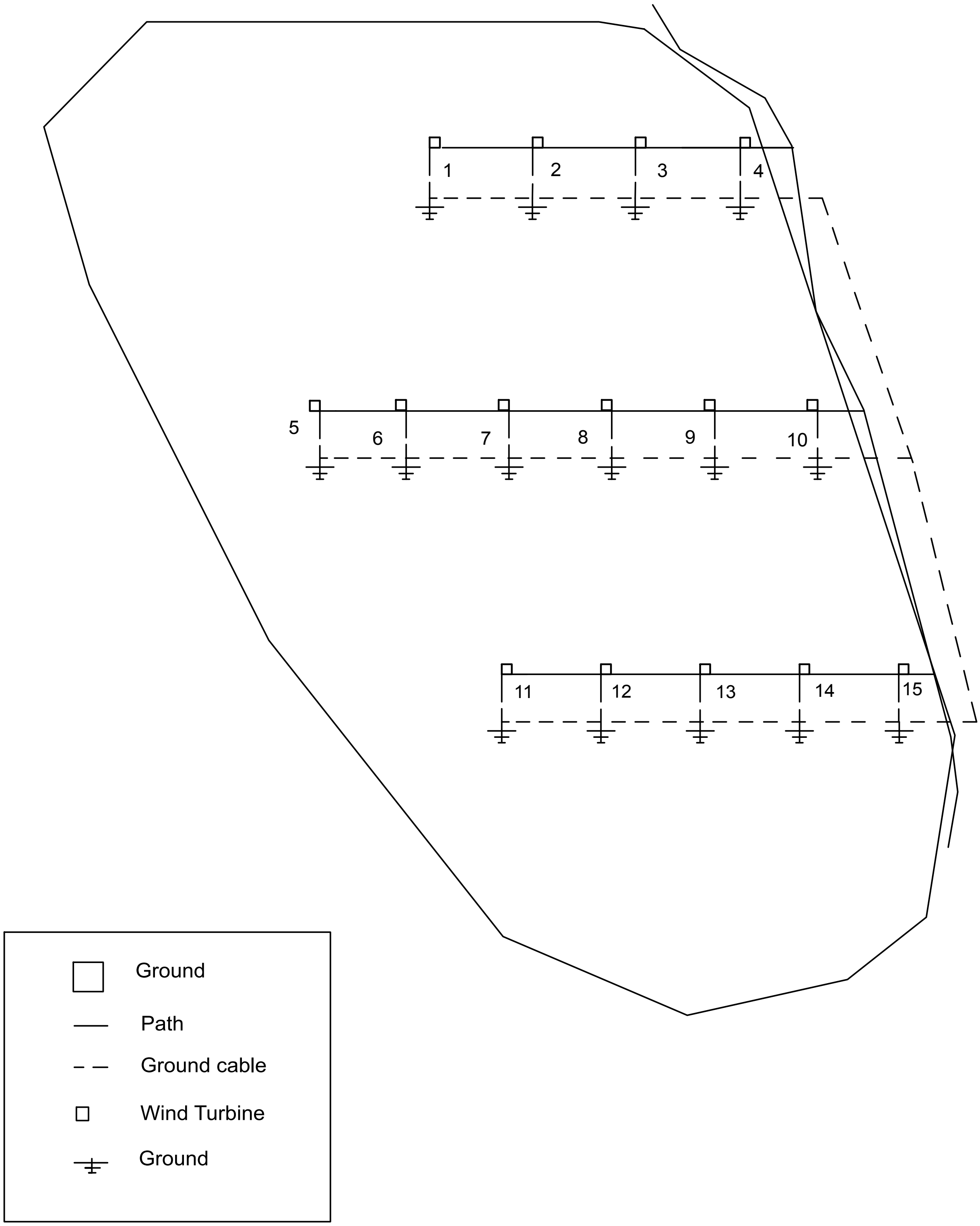
Ground

Path

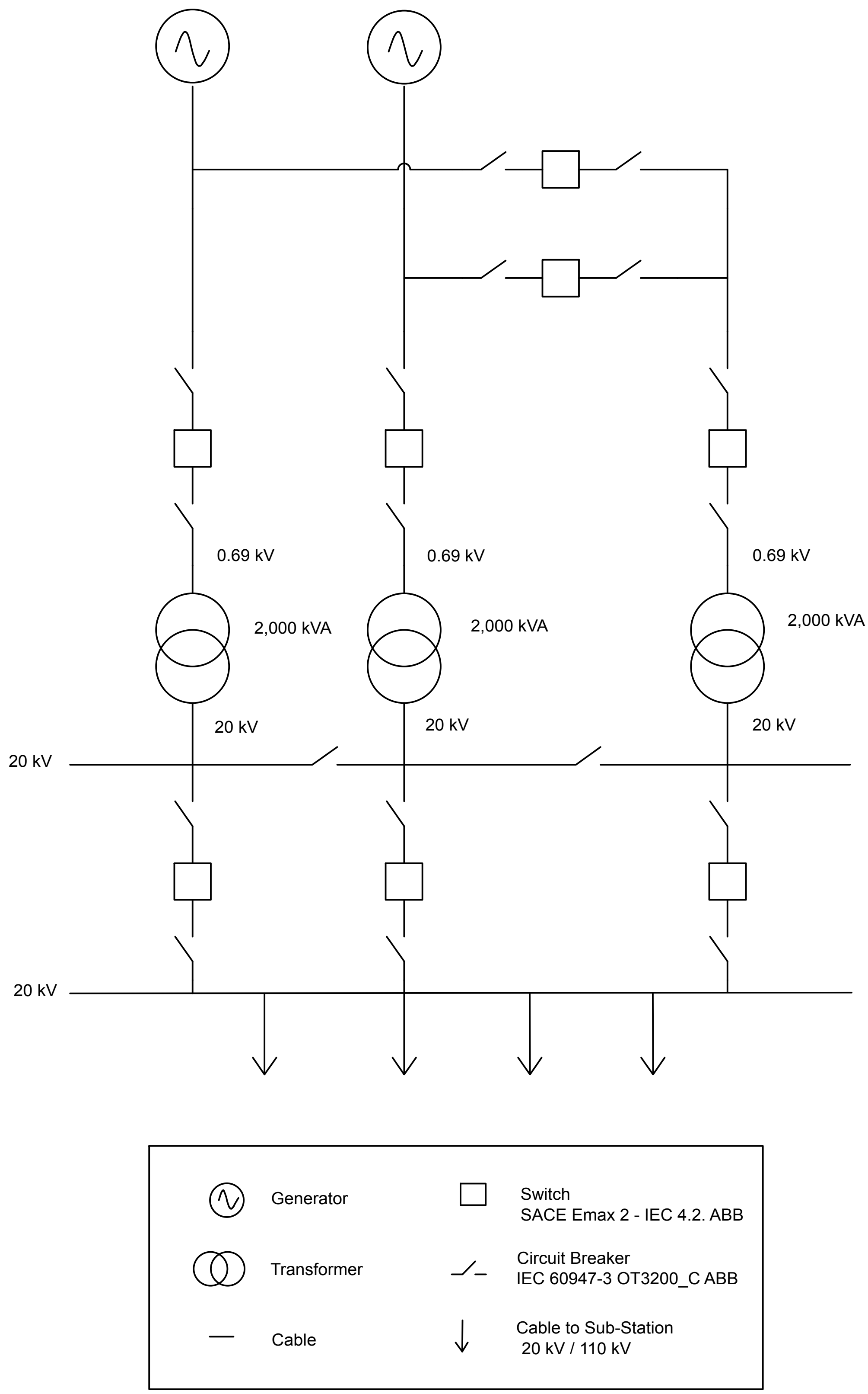
TECHNICAL UNIVERSITY OF SOFIA	FINAL PROJECT	Autor: ANA SASTRE GÓMEZ
Project: WIND FARM PROJECT		Signature:
Name: Google Maps Location	Number: 1	Date: 25/04/16	Scale:



TECHNICAL UNIVERSITY OF SOFIA	FINAL PROJECT	Autor: ANA SASTRE GÓMEZ
Project: WIND FARM PROJECT		Signature:
Name: Location of wind turbines		Number: 2 — Date: 25/04/16 — Scale: 1:2500



TECHNICAL UNIVERSITY OF SOFIA	FINAL PROJECT	Autor: ANA SASTRE GÓMEZ
Project: WIND FARM PROJECT		Signature:
Name: Grounding of wind farm		Number: 3 | Date: 25/04/16 | Scale: 1:2500



TECHNICAL UNIVERSITY OF SOFIA

FINAL PROJECT

Autor:

ANA SASTRE GÓMEZ

Project:

WIND FARM PROJECT

Signature:

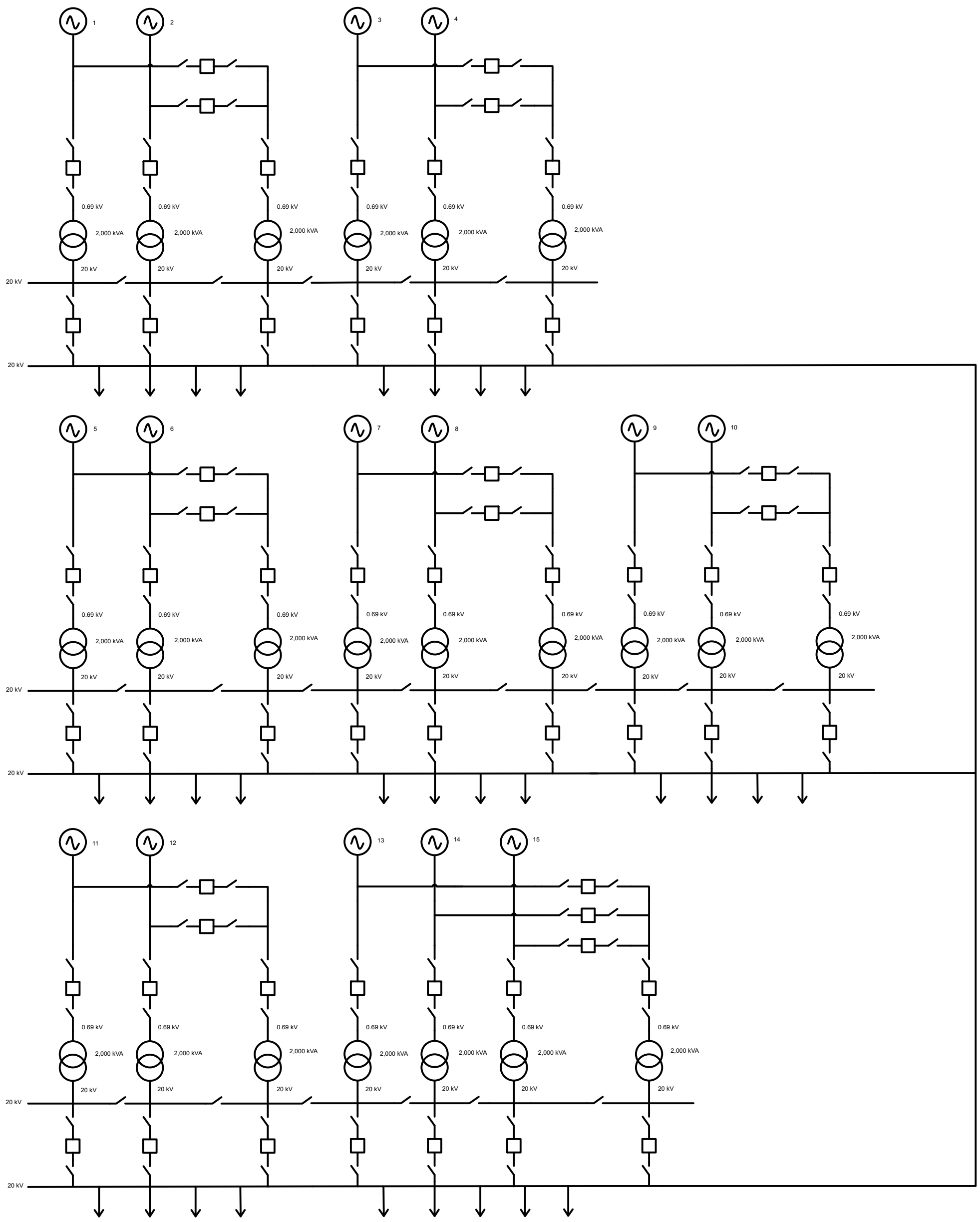
Name:

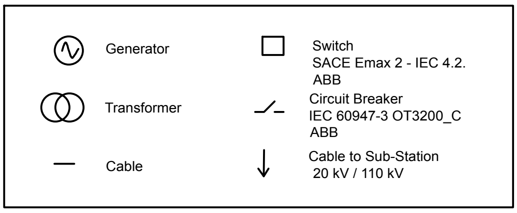
Electrical connections of two wind turbines

Number: 4

Date: 25/04/16

Scale:





TECHNICAL UNIVERSITY OF SOFIA	FINAL PROJECT	Autor: ANA SASTRE GÓMEZ
Project: WIND FARM PROJECT		Signature:
Name: Electrical Connections of the wind farm		Number: 5 · Date: 25/04/16 · Scale:

ANNEXES

1. GAMESA WIND TURBINE DATA
2. ABB SWITCH DATA
3. ABB CIRCUIT BREAKER DATA

G97-2.0 MW

Innovación tecnológica y experiencia

El aerogenerador G97-2.0 MW, desarrollado dentro de la plataforma de 2.0 MW, la más versátil del mercado, es la respuesta de Gamesa a la creciente demanda de soluciones tecnológicas que garanticen mayor producción en emplazamientos de vientos bajos y moderados.

Con 22 GW instalados en 37 países y niveles de disponibilidad por encima del 98%, la plataforma Gamesa 2.0 MW es una de las soluciones más exitosas del mercado. Hoy, con el nuevo aerogenerador G97-2.0 MW, Gamesa ofrece a sus clientes aún más.

- MÁXIMA PRODUCCIÓN Y MÍNIMO COSTE DE ENERGÍA
- MÁXIMA RENTABILIDAD
- FIABILIDAD

FIABILIDAD Y MADUREZ TECNOLÓGICA

El aerogenerador G97-2.0 MW hereda la mayoría de los conceptos tecnológicos, subsistemas y componentes desarrollados y optimizados para la plataforma Gamesa 2.0 MW a lo largo de más de 10 años de experiencia probada, introduciendo las mejoras y adaptaciones necesarias para resistir las cargas asociadas a un rotor más grande.

>> Nacelle

Se introducen refuerzos y mejoras a componentes clave como el tren de potencia, el sistema de yaw, el eje principal, los rodamientos de pala y el bastidor. Imagen renovada de la nacelle con un diseño más atractivo y mayor espacio para agilizar las operaciones de mantenimiento.

>> Pala

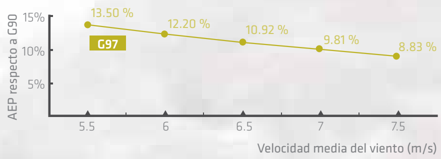
Los nuevos perfiles aerodinámicos, íntegramente desarrollados por Gamesa y optimizados para vientos bajos y medios, garantizan la máxima producción de energía, reduciendo al mínimo los niveles de emisión de ruido y las cargas aerodinámicas sobre la nacelle. Asimismo la introducción de elementos en fibra de carbono reduce el peso de la pala, manteniendo su robustez y resistencia.

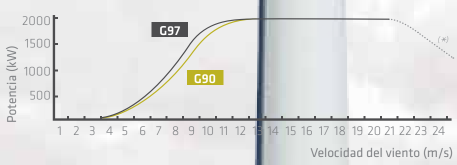
>> Torre

Nueva altura de torre disponible: 120 m.

MÁXIMA PRODUCCIÓN

Con un rotor de 97 m, que incrementa en un 16% el área de barrido del aerogenerador G90-2.0 MW, el nuevo modelo G97-2.0 MW ofrece hasta un 14% más de producción de energía anual.





** Versión de control con derating no disponible en España hasta septiembre de 2016.*

ESPECIFICACIONES TÉCNICAS

Datos Generales	
Potencia nominal	2.0 MW
Clase de viento	IIA/IIIA
Nivel de emisión de ruido	104,5 dB(A) a potencia nominal
Control de ruido	Gamesa NRS®
Rango de temperatura	-30°C a +40°C (+45°C con de rating)
Opciones ambientales	Disponibles versiones para emplazamientos en altitud y para ambientes polvorientos y de alta corrosión.
Velocidad de cut-in	3 m/s
Velocidad de cut-out	25 m/s (filtro de 100s)
Rotor	
Diámetro	97 m
Área de barrido	7.390 m2
Velocidad de giro	9,6 – 17,8 rpm
Control	Pitch y velocidad variable
Palas	
Longitud	47,5 m
Perfil	Gamesa
Material	Fibra de vidrio pré-impregnado de resina epoxi + fibra de carbono

Torres	
Altura	78, 90, 100, 104[(1)], 120 m
Multiplicadoras	
Tipo	1 etapa planetaria 2 etapas de ejes paralelos
Ratio	1:106,8 (50Hz) 1:127,1 (60Hz)
Generador	
Tipo	Generador doblemente alimentado.
Tensión	690 V AC
Frecuencia	50 Hz / 60 Hz
Clase de protección	IP54
Factor de potencia	0,95 CAP – 0,95 IND en todo el rango de potencia
HITOS PRINCIPALES	
G97 IIIA	
Primer prototipo	2011
Producción en serie	2011
Certificado Tipo	Disponible (DNV)
G97 IIA	
Primer prototipo	2012
Producción en serie	2012
Certificado Tipo	Disponible (DNV)

(1) Clase S.

Con el fin de causar el menor impacto medioambiental, este documento se ha impreso en papel fabricado con un 50% de pura celulosa (ECF), un 40% de fibra reciclada seleccionada pre-consumer y un 10% de fibra reciclada y destinada post consumer. Tintas basadas exclusivamente en aceites vegetales con un mínimo contenido en compuestos orgánicos volátiles (VOC´S). Barniz basado predominantemente en materias primas naturales y renovables.

Fecha de impresión: Enero 2016

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Tel: +90 212 340 76 00

Technical catalogue - Edition 03.2013 - Preliminary

SACE Emax 2
New low voltage air circuit-breakers

Power and productivity
for a better world™

ABB

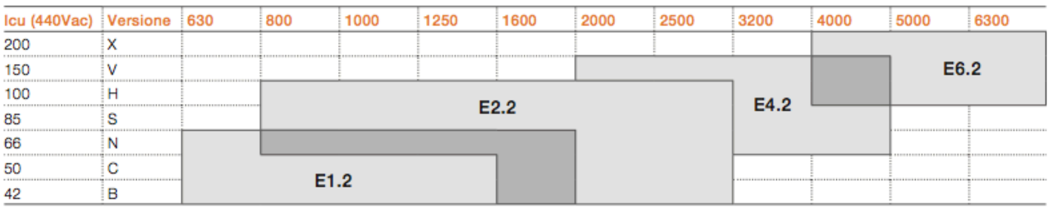
Overview of the SACE Emax 2 family

1 Guide to selection

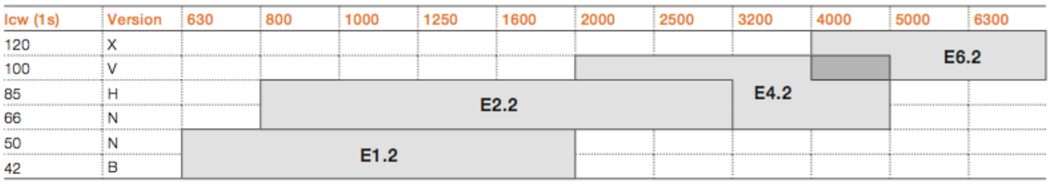
Ranges available

	E1.2	E2.2	E4.2	E6.2
Automatic circuit-breakers @ 690-1150 V AC	•	•	•	•
Switch-disconnectors @ 690-1150 V AC, 1000 V DC	•	•	•	•
Sectionalizing truck		•	•	•
Earthing switch with making capacity		•	•	•
Earthing truck		•	•	•

Automatic circuit-breakers



Switch-disconnectors



Protection trip units

Version	Application		
	Distribution	**Power control**	**Generators**
Ekip Dip	Protection devices	-	-
Ekip Touch	Protection devices and Measurements	Protection devices and Measurements	-
Ekip Hi-Touch	Protection devices, Measurements, Network analyzer	Protection devices, Measurements, Network analyzer	-
Ekip G Touch		Protection devices and Measurements	Protection devices and Measurements
Ekip G Hi-Touch		Protection devices, Measurements, Network analyzer	Protection devices, Measurements, Network analyzer

Distinctive features

1

Key
1 Trademark and size of circuit- breaker
2 SACE Ekip protection trip unit
3 Pushbutton for manual opening
4 Pushbutton for manual closing
5 Lever to manually charge closing springs
6 Electrical rating plate
7 Mechanical device to signal circuit-breaker open "O" and closed "I"
8 Signal for springs charged or discharged
9 Mechanical signalling of overcurrent release tripped
10 Size and serial number

SACE Emax 2 automatic circuit-breakers

Common data		
Rated service voltage Ue	[V]	690
Rated insulation voltage Ui	[V]	1000
Rated impulse withstand voltage Uimp	[kV]	12
Frequency	[Hz]	50 - 60
Number of poles		3- 4
Version		Fixed - Withdrawable
Isolation behaviour		IEC 60947-2


1SDC200424F001

SACE Emax 2			E1.2			
Performance levels			B	C	N	L
Rated uninterrupted current Iu @ 40°C		[A]	630	630	250	630
		[A]	800	800	630	800
		[A]	1000	1000	800	1000
		[A]	1250	1250	1000	1250
		[A]	1600	1600	1250	
		[A]			1600	
		[A]				
Neutral pole current-carrying capacity for 4-pole CBs		[%Iu]	100	100	100	100
Rated ultimate short-circuit breaking capacity Icu	400-415 V	[kA]	42	50	66	150
	440 V	[kA]	42	50	66	130
	500-525 V	[kA]	42	42	50	100
	690 V	[kA]	42	42	50	60
Rated service short-circuit breaking capacity Ics		[%Icu]	100	100	100[1)]	100
Rated short-time withstand current Icw	(1s)	[kA]	42	42	50	15
	(3s)	[kA]	24	24	36	-
Rated short-circuit making capacity (peak value) Icm	400-415 V	[kA]	88	105	145	330
	440 V	[kA]	88	105	145	286
	500-525 V	[kA]	88	88	105	220
	690 V	[kA]	88	88	105	132
Utilization category (according to IEC 60947-2)			B	B	B	A
Breaking	Breaking time for I<Icw		40	40	40	40
	Breaking time for I>Icw		25	25	25	10
Dimensions	H - Fixed/Withdrawable	[mm]	296/363.5	296/363.5	296/363.5	296/363.5
	D - Fixed/Withdrawable	[mm]	183/271	183/271	183/271	183/271
	W - Fixed 3p/4p/4p FS	[mm]	210/280			
	W - Withdrawable 3p/4p/4p FS	[mm]	278/348			

1) Ics : 50kA for 400V...440V voltage

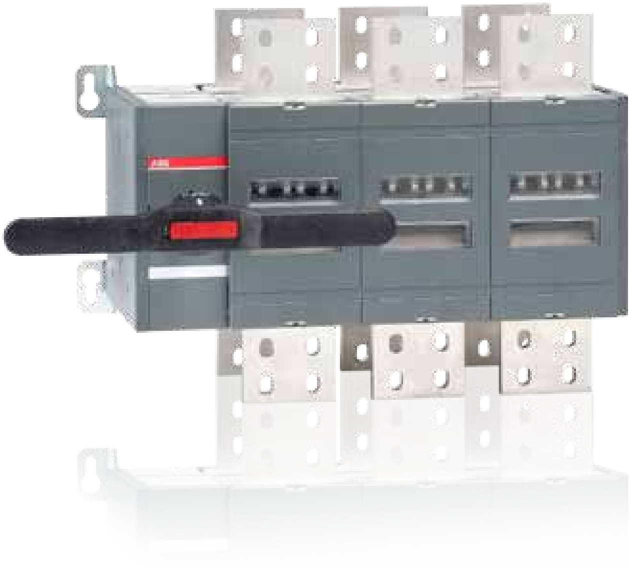
SACE Emax 2			E1.2			
Mechanical and electrical life with regular ordinary maintenance prescribed by the manufacturer		[Iu]	≤ 1000	1250	1600	1600 L
		[No.oper.x 1000]	20	20	20	20
	Frequency	[Oper./Hour]	60	60	60	60
Electrical life	440 V	[No.oper.x 1000]	8	8	8	3
	690 V	[No.oper.x 1000]	8	6,5	6,5	1
	Frequency	[Oper./Hour]	30	30	30	30

	E2.2				E4.2				E6.2		
	B	N	S	H	N	S	H	V	H	V	X
	1600	800	250	800	3200	3200	3200	2000	4000	4000	4000
	2000	1000	800	1000	4000	4000	4000	2500	5000	5000	5000
		1250	1000	1250				3200	6300	6300	6300
		1600	1250	1600				4000			
		2000	1600	2000							
		2500	2000	2500							
			2500								
	100	100	100	100	100	100	100	100	50-100	50-100	50-100
	42	66	85	100	66	85	100	150	100	150	200
	42	66	85	100	66	85	100	150	100	150	200
	42	66	66	85	66	66	85	100	100	130	130
	42	66	66	85	66	66	85	100	100	100	120
	100	100	100	100	100	100	100	85	100	100	100
	42	66	66	85	66	66	85	100	100	100	120
	42	50	50	66	36	50	66	75	100	100	100
	88	145	187	220	145	187	220	330	220	330	440
	88	145	187	220	145	187	220	330	220	330	440
	88	145	145	187	145	145	187	220	220	286	286
	88	145	145	187	145	145	187	220	220	220	264
	B	B	B	B	B	B	B	B	B	B	B
	40	40	40	40	40	40	40	40	40	40	40
	25	25	25	25	25	25	25	25	25	25	25
	371/425	371/425	371/425	371/425	371/425	371/425	371/425	371/425	371/425	371/425	371/425
	270/383	270/383	270/383	270/383	270/383	270/383	270/383	270/383	270/383	270/383	270/383
	276/366				384/510				762/888/1014		
	317/407				425/551				803/929/1069		

	E2.2				E4.2				E6.2		
	< 1600	1600	2000	2500	< 2500	2500	3200	4000	4000	5000	6300
	25	25	25	20	20	20	20	15	12	12	12
	60	60	60	60	60	60	60	60	60	60	60
	15	12	10	8	10	8	7	5	4	3	2
	15	10	8	7	10	8	7	4	4	2	2
	30	30	30	30	20	20	20	20	10	10	10

New change-over switches 3200 Amperes
Compact and robust design

Minimizing the need for space – The design of ABB change-over switch OT3200 is advanced and compact especially when compared to different transfer device technologies. Compact double layer construction allows installation in confined spaces at considerable savings. For demanding conditions – Highest short-circuit ratings on the market, I_{cw} 65 kA 1s, I_{cm} 143 kA 500 V.



Technical data

Data according to IEC 60947-3				Switch size OT3200_C
Rated insulation voltage and rated operational voltage AC20/DC20		Pollution degree 3	V	1 000
Dielectric strength		50 Hz 1min.	kV	10
Rated impulse withstand voltage			kV	8
Rated thermal current and rated operational current AC20/DC20	/ ambient 40°C	In open air	A	3200
..with minimum conductor cross section		Cu	mm^2	4 x 1 000
Rated operational current, AC-21B		up to 415 V	A	3 200
Rated short-time withstand current	I_{cw} (r.m.s.)	500 V 1s	kA	65
Rated short-time making capacity[1]	I_{cm} (peak)[2]	500 V	kA	143
Weight without accessories		3-pole	kg	57
		4-pole	kg	72

[1] Short circuit duration > 50ms, without fuse protection
[2] Max. distance from switch frame to nearest busbar / cable support 150 mm

Ordering information

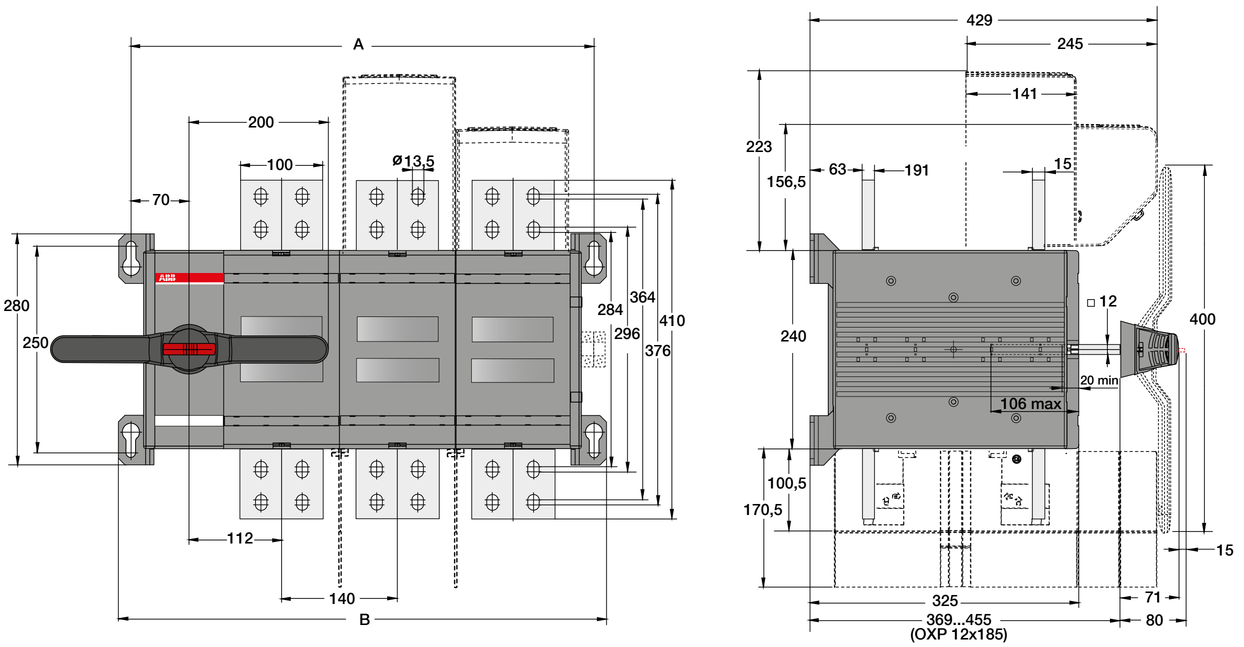
No. of poles	Rated current and power, AC-21B ≤ 415V I[A]	400V S[kVA]	Type	Order number	Units/ type [pcs]	Weight/ unit [kg]
Manual change-over switches, I-0-II -operation, open transition, IEC-types						
Including a black plastic IP65 I-0-II double pistol type handle, see the table below, shaft and bolt set for the cable connection. Handle padlockable in the 0-position, door interlock in the I- and II-positions and when padlocked.						
3	3200	2170	OT3200E03CP	1SCA129156R1001	1	79
4	3200	2170	OT3200E04CP	1SCA129158R1001	1	97

Shafts, handle and bolt kits included as standard

Suitable for switches	Shaft	Handle	Bolt kit
OT3200_C	OXP12x185	OHB200J12PE011	M12x100

Dimension drawings

OT3200E03/04CP



OTC30GB 14-02, 1SCC303011K0201

M00435/OT3200E02-04C B/ES

OT3200_C		
[mm]	EE03	E04
A	560	700
B	590	730

For more information please contact:

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